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TRANSACTIONS

OF THE

Illinois State Academy of Science

SEVENTH ANNUAL MEETING

Evanston, Ill., Feb. 20 and 21, 1914

VOLUME VII

1914

OHIO STATE UNIVERSITY

PUBLISHED BY THE ACADEMY

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Edited By
A. R. CROOK
1915–1916

OHIO STATE
UNIVERSITY

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OFFICERS AND COMMITTEES FOR 1914-1915

President, A. R. CROOK, Curator State Museum of Natural History, Springfield.
Vice-President, U. S. GRANT, Northwestern University, Evanston.
Secretary, E. N. TRANSEAU, State Normal School, Charleston.
Treasurer, JOHN C. HESSLER, James Millikin University, Decatur.

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PRESIDENT, VICE PRESIDENT, PAST PRESIDENT, SECRETARY, AND TREASURER

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PRESIDENT, SECRETARY, TREASURER, AND S. A. FORBES.

Committee on Membership

H. C. COWLES, Chairman, Chicago.
RUTH MARSHALL, Rockford.
H. B. SHINN, Chicago.
FAITH MCAULEY, St. Charles.
R. E. WAGER, DeKalb.

Committee on Legislation

A. R. CROOK, Chairman, Springfield.
WILLIAM BARNES, Decatur.
ALICE PATTERSON, Normal.
E. O. JORDAN, Chicago.
T. L. HANKINSON, Charleston.

Committee on Calendar Reform

F. R. MOULTON, Chairman, Chicago.
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C. G. HOPKINS, Urbana.
E. J. TOWNSEND, Urbana.
T. C. CHAMBERLIN, Chicago.

Committee on Secondary Science.

W. W. WHITNEY, Chairman, Chicago.
O. W. CALDWELL, Chicago.

Committee on Ecological Survey.

S. A. FORBES, Chairman, Urbana.
H. C. COWLES, Chicago.
T. L. HANKINSON, Charleston.
V. E. SHELFORD, Urbana.
E. N. TRANSEAU, Charleston.
F. C. BAKER, Chicago.
H. S. PEPOON, Chicago.
G. D. FULLER, Chicago.

PAST OFFICERS OF THE ACADEMY

1908

President, T. C. CHAMBERLIN, University of Chicago.
Vice-President, HENRY CREW, Northwestern University.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1909

President, S. A. FORBES, University of Illinois.
Vice President, JOHN M. COULTER, University of Chicago.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1910

President, JOHN M. COULTER, University of Chicago.
Vice-President, R. O. GRAHAM, Illinois Wesleyan University.
Secretary, A. R. CROOK, State Museum of Natural History.
Treasurer, J. C. HESSLER, James Millikin University.

1911

President, W. A. NOYES, University of Illinois.
Vice-President, J. C. UDDEN, University of Texas.
Secretary, FRANK C. BAKER, Chicago Academy of Science.
Treasurer, J. C. HESSLER, James Millikin University.

1912

President, HENRY CREW, Northwestern University.
Vice-President, A. R. CROOK, State Museum of Natural History.
Secretary, OTIS W. CALDWELL, University of Chicago.
Treasurer, J. C. HESSLER, James Millikin University.

1913

President, FRANK W. DEWOLF, State Geological Survey.
Vice-President, H. S. PEPOON, Lake View High School, Chicago.
Secretary, E. N. TRANSEAU, Eastern Illinois Normal School.
Treasurer, J. C. HESSLER, James Millikin University.

Minutes of The Seventh Annual Meeting

NORTHWESTERN UNIVERSITY
EVANSTON, ILLINOIS, FEBRUARY 20-21, 1914

After call to order by President DeWolf, Professor Henry Crew of Northwestern University gave an address of welcome to which President DeWolf responded. This was followed by the President's address on "Recent Investigations of the Mineral Resources of the Country."

The following papers were then presented: "Earth Tides," A. A. Michelson; "The International Phytogeographical Excursion," Henry C. Cowles; "Recent Theories of Fertilization and Parthenogenesis," F. R. Lillie.

At six-thirty about one hundred members of the Academy were welcomed by President Harris of Northwestern University at a banquet in the University Gymnasium.

At eight o'clock the Northwestern Chapter of Sigma Xi gave a reception at Science Hall in the Physics Laboratory.

On Saturday morning, February 22, reports of the officers and committees were given, as follows:

THE SECRETARY'S REPORT

The sixth annual meeting of the Academy was held at Peoria, February 21 and 22, 1913, in the auditorium of the Bradley Polytechnic Institute. A Symposium on Sanitation was presented in the morning and a lecture by Prof. Barnard on "Some Late Results in Astronomical Photography," in the evening. The proceedings in full are given in Vol. VI. of the Academy's Transactions. At a meeting of the Council in the office of the Geological Survey, Urbana, November 22, 1913 it was decided to hold the seventh annual meeting at Northwestern University, February 20 and 21, 1914, and to recommend that the eighth annual meeting be held at Springfield. February 19 and 20, 1915. By having the place of meeting understood a year in advance it was thought that certain advantages would accrue to the Academy. The publication com-

mittee was authorized to proceed with the printing of the Transactions. Professor Forbes and President DeWolf were asked to draw up a legislative bill authorizing the State Board of Contracts to publish the Transactions of the Academy in the future. Professor J. S. Compton was elected a member subject to the approval of the Academy. Plans for the Evanston meeting were discussed.

Membership. At the Peoria meeting forty-six new members were added, making the mailing list for 1913 total 390 names—five less than during the preceding year. This number could readily be doubled if active members would each make an effort to secure at least one new member this year.

EDGAR N. TRANSEAU, Secretary.

COMMITTEES ON LEGISLATION, HIGH SCHOOL LEAFLETS AND HIGH SCHOOL SCIENCE

For the Committee on Legislation, Dr. A. R. Crook gave a verbal report.

The Committee on High School Leaflets, reported by way of a letter from Dr. John G. Coulter, that the plan of publication originally outlined by the committee would not pay if made a state affair.

As a report of the Committee on Pure and Applied Science in High Schools, W. W. Whitney, chairman, offered the two papers by H. B. Shinn and A. W. Nolan, which appear further along in the volume.

On motion of W. L. Eikenberry, the name of the Committee on Pure and Applied Science in High School was changed to Committee on Secondary Science. On motion of A. R. Crook it was decided to form a new committee on Calendar Reform. consisting of F. R. Moulton, chairman; A. R. Crook, C. G. Hopkins, E. J. Townsend and T. C. Chamberlin, the last named having requested to be relieved of the chairmanship.

The Auditing Committee, consisting of L. M. Umbach, G. D. Fuller and R. R. Tatnall, reported the books of the treasurer in good condition, and the statements as given in his report correct.

The Nominating Committee, consisting of C. B. Atwell, chairman, C. M. Turton, Ruth Marshall and J. L. Smith, made

the following report of nominations for officers which was adopted by the Academy:

President—A. R. Crook, Springfield.

Vice-President—U. S. Grant, Evanston.

Secretary—E. N. Transeau, Charleston.

Treasurer, J. C. Hessler, Decatur.

Membership Committee—H. C. Cowles, chairman, Chicago; Ruth Marshall, Rockford, H. B. Shinn, Chicago, Faith McAuley, St. Charles, R. E. Wager, DeKalb.

Legislative Committee—A. R. Crook, Springfield, William Barnes, Decatur, Alice Patterson, Normal, E. O. Jordan, Chicago, T. L. Hankinson, Charleston.

In adopting the report of the Secretary the Academy voted to hold the meeting of 1915 in Springfield.

The Committee on Resolutions, consisting of F. C. Baker, chairman, offered the following resolutions which were unanimously adopted by the Academy:

Resolved, That the Illinois Academy of Science hereby expresses its appreciation and thanks for the cordial reception and the generous manner in which it has been entertained during the 1914 meeting by the president and the members of the faculties of the scientific department of the Northwestern University.

Resolved, That the Illinois Academy of Science hereby expresses its appreciation of the reception tended by the officers and members of the Northwestern Chapter of the Sigma Xi Society.

On motion duly seconded, the Seventh Annual meeting adjourned.

E. N. TRANSEAU, Secretary.

REPORT OF THE TREASURER

February 20, 1914.

RECEIPTS

Balance on hand February 22, 1913	$ 88.82
Received from membership fees	195.00
Received from initiation fees	20.00
Received from exchange on checks	.25
Total receipts	$304.07

EXPENDITURES

To O. W. Caldwell, sec'y., postage and expenses attending Peoria meeting		$19.43
To University of Chicago Press, printing		11.75
To John C. Hessler, Treas., postage Nov. 26, 1912, to Feb. 21, 1913	$0.95	
Postage Feb. 26, 1913, to Dec. 29, 1913	9.11	13.96
To H. C. Sampson, Chicago, addressing		1.85
To West Paper Co., Decatur, 400 printed postal cards		5.65
To O. W. Caldwell, Sec'y, telephone, stamps, drayage		4.50
To E. N. Transeau, Sec'y, freight and postage		3.02
To Charleston Courier, letter-heads, envelopes		8.00
Total expenditures		$68.16

SUMMARY

Total receipts, Feb. 22, 1913, to Feb. 20, 1914	$304.07
Total expenditures	68.16
Balance on hand Feb. 20, 1914	$235.91

J. C. HESSLER, Treasurer.

REPORT OF THE COMMITTEE ON CONSERVATION

Your committee continued from 1913, appointed to confer with the railways of Illinois regarding the possibility of establishing plant reservations along the rights of way, begs leave to make final report as follows, and asks to be discharged from further efforts.

The Illinois Central Railway, as owner of the oldest established right of way in the state, was asked to join with the Academy in establishing 24 plant preserves of limited area in various counties from Jo Daviess to Alexander. If the railway company would abstain from mowing such preserves until after seeding time the Academy would properly placard them and interest local botanists in their continuance and upkeep. In this way many rare and rapidly vanishing prairie plants, such as Habenaria leucophoea, Liliums superbum and Philadelphicum, Ranunculus ovalis, Geum ciliatum, Acuan Illinoensis, Baptisia leucophoea, Psoralea tenuiflora, Amorpha canescens, Petalostemum candidum, Linum sulcatum, Polygala incarnata.

Violas pedatifida and pedata bicolor, Gaura biennis, Polytaenia nuttallii, Gentiana puberula, Asclepias sullivantii, A. rubra, A. verticillata, Phlox maculata, P. glaberrima, Liatris, Grindelia squarrosa, Echinacea purpurea and others might be saved.

The chief engineer of the railroad replied that the sections set apart would be untidy in appearance, occasion hazard from fire and endanger adjoining property, and if allowed to mature would go to seed and thus disseminate objectionable plants. He asked if the Academy would be willing to guarantee the railroad company against trouble by fire and would run plowed furrows around the areas planted at certain regular intervals. As the Academy would not undertake to carry out the propositions presented the matter was dropped.

H. S. Pepoon, Chairman.

REPORT OF THE COMMITTEE ON AN ECOLOGICAL SURVEY OF THE STATE

Your Committee on an Ecological Survey has to report that its work has been, during the past year, of substantially the same character as heretofore, the various members of the committee being severally engaged on their separate problems, co-operating by conference rather than by means of plans systematically co-ordinated in advance. Each of us is, in fact, so limited by location, official and educational engagements, and the like, that any more compact organization of our studies seems for the present impracticable. The ecologists of the Chicago area are, however, making steady and substantial progress towards a complete ecological survey of their territory. Elsewhere in the state our work has been virtually limited to the operations of the State Laboratory of Natural History together with the State Entomologist's office, the work of Doctor Adams's students at the University of Illinois, and the studies of Transeau and Hankinson at the Eastern Illinois State Normal School.

The most important items of progress during the year are three publications by members of the committee: Shelford's volume on animal communities in temperate America as illustrated in the Chicago region; Adams's guide to the study of animal ecology; and Forbes and Richardson's studies on the biology of the upper Illinois River, published as a bulletin of the Illinois State Laboratory of Natural History. The vol-

umes by Shelford and Adams are invaluable to the student of ecology, supplying means of guidance, models of work, statements of principles, summaries of existing knowledge, and comprehensive references to literature, hitherto altogether wanting. Forbes and Richardson's work on the Illinois River has principal reference to pollutional effects and to fisheries, but takes into account the whole system of life from the microscopic plankton to the vertebrates, with only slight reference, however, to the larger plants. It represents the first attempt made in this country to correlate lists of biological species with degrees of contamination of the water, in a way to make the former an index to the latter. The paper has attracted the special attention of sanitary engineers. Besides the various ecological papers by Transeau, Hankinson, Harvey, and Fuller in the last volume of the Trasactions of the Academy, honorable mention should be made of a report on an Associational Study of Illinois Sand Prairies, by Arthur G. Vestal, which has been published, within the year, as a bulletin of the State Laboratory of Natural History.

The field work of the State Laboratory of Natural History has been devoted almost entirely to the Illinois River situation, in the form of a survey of the plant and animal life of the river and connected waters of the bottom-lands from Peoria to the mouth of the stream. The collections, mainly from the bottom and shores of the waters, were comprehensive of all animal forms except those of the plankton, and were made as nearly as practicable by quantitative methods, for the purpose of comparing the productivity of different waters and different parts of the stream system. Samples of the bottom sediments of the waters were systematically taken from a large variety of situations, and are now in process of analysis at the Chemical Laboratory of the University of Illinois. Regular series of water samples from various points down the river are also being obtained for analysis in the laboratories of the State Water Survey, the object of this study being to trace the transformations of sewage materials down the stream and to learn where they first become most available for the nutrition of plants and animals. Thorough statistical studies of the fisheries products of different sections of the Illinois River for a period of years have also been made, with some important economic consequences which will be presently detailed in a bulletin of the State Laboratory of Natural History, giving the product of the season's work.

Doctor Adams has completed his part of the report on the

Charleston survey, and this will presently be in press as a bulletin of the State Laboratory.

Doctor Shelford has made an extensive study of the behavior characters of an animal community inhabiting a swift stream. The results show that the various species of animals of this community are in agreement with respect to their reactions to current and bottom—that is, they select stones and avoid sand, and select strong current, placing themselves with their heads upstream. Their reactions to light and the positions they take up with reference to stones in the experiments, are in accord with their distribution in the rapids. The animals of a pool community, studied in a similar way, were found to give reactions decidedly different from those of the rapids community. Physiological responses are thus shown to be matters of the first importance in ecology.

Doctor Pepoon has accumulated further data in his study of the flora of the Chicago area, his list of which now numbers 1,800 species of the higher plants. He is studying the flora of the north shore as far as Waukegan, and Dr. Frank Gates has the Waukegan area itself. In connection with these studies, Prof. E. J. Hill is working upon the ecology of the Calumet-Des Plaines region, and Prof. L. M. Umbach on that of the DuPage valley area. It is hoped that the manuscript of this co-operative group may be ready for the printer by April 15. Doctor Pepoon has also begun an elaborate paper on the driftless area of Jo Daviess county, which will bring together all his materials concerning the plant problems of this peculiar region.

Mr. Baker is continuing his interesting studies comparing the remains of glacial life found in the deposits of Lake Chicago with the post-glacial plants and animals of the Great Lake region, with special reference to the origin of our present fauna and flora. These studies have extended to southwestern Michigan, where there are sedimentary deposits of the middle and later stages of the lake. Ancient marl beds in Pipestone Lake, Magician Lake, and in the old swamp near Buchanan have been examined, and their relation to the ancient Chicago outlet and to the old Kankakee outlet is now being worked out. Mr. Baker's work on Pleistocene life is now nearly completed, and embraces a list of all the plants and animals recorded from inter-glacial and post-glacial deposits of all the states surrounding the Great Lake region and southern Canada.

Doctor Cowles's personal work during the past year has lain outside the state, together with a large part of the work of his students. One of the latter, Mr. Ullrich, has maintained during the summer season a large number of atmometer stations for an extensive study of the moisture conditions of a ravine near Glencoe, Ill. Exact evaporation data were obtained for different situations in various parts of the ravine; and the soil moisture was determined weekly in a way to give the range of conditions throughout the season. The wilting co-efficient of the soils having been determined, the approximate amount of moisture available for plant growth was shown.

Mr. Hankinson is preparing for publication his data of the survey of the prairie and forest near Charleston, made in August, 1910, in co-operation with Adams and Transeau.

Doctor Transeau has continued his work on the periodicity of the occurrence and reproduction of the Algae. During the year past an attempt has been made to analyze the environmental factors related to these changes in the Algae. In addition to temperature records, the variations in the osmotic pressure of natural waters have been studied by means of the freezing-point method. These data have shown that, contrary to the accepted notion, when ponds and pools dry up in the summer, the concentration of the solution is not increased, but is usually greatly diminished. The highest concentrations occur during the periods of high water in spring, and during the early rainy period of autumn.

The evaporation rates and the soil moisture conditions in several of the forest-plant associations of the Chicago area. and in some bits of undisturbed prairie have been studied in a quantitative manner by Dr. Geo. D. Fuller and some of his students during the past four years. An attempt has been made, with considerable success, to relate these determinations to the succession of plant associations. These studies include areas at Miller, and Otis, Ind., Palos Park, and Chicago Lawn, Ill. A paper by Mr. J. F. Graves upon the present program gives some of the results of his studies in evaporation and soil moisture conditions in cultivated and natural areas. The data obtained during the years 1910-1913 have been collected by Dr. Fuller, and are now in manuscript and will be published at an early date.

We have finally to report action taken yesterday by your committee, looking to a program of correspondence and inquiry, and a search for relic situations characteristic of the more important ecological features of primitive Illinois. Such

situations being found, fairly convenient of access from centers of investigation, it is believed by us that graduate students and others can be interested to study and report upon them, provided that some allowance of money can be made to cover the expense of the necessary travel; and some such co-operation the director of the State Laboratory of Natural History, who is also chairman of this committee, is prepared to offer us because of the importance of such studies as a contribution to the natural history survey of the state, in progress under his direction.

By the Committee:

CHARLES C. ADAMS,
FRANK C. BAKER,
HENRY C. COWLES,
GEORGE D. FULLER,
THOMAS L. HANKINSON,
HERMANN S. PEPOON,
VICTOR E. SHELFORD,
EDGAR N. TRANSEAU,
STEPHEN A. FORBES,
Chairman.

Evanston, Illinois, February 20, 1914.

THE PRESIDENT'S ADDRESS

Investigations of Mineral Resources and Industries of the United States

BY F. W. WOLF, DIRECTOR STATE GEOLOGICAL SURVEY

The importance of the United States as a producer and reserve supply of mineral for the World is not commonly realized. According to the latest available figures of the U. S. Geological survey, the country ranks first for eight minerals, and produces percentages of the world's output, (Figures 1 and 2) in each mineral, listed as follows:

Petroleum	64 percent
Smelted Copper	56 percent
Phosphate and Gypsum	50 percent
Iron	40 percent
Coal	38 percent
Lead	33 percent
Zinc	29 percent
Tungsten	28 percent

The history of mineral investigations and a review of their character will, I hope, be interesting to those Academy mem-

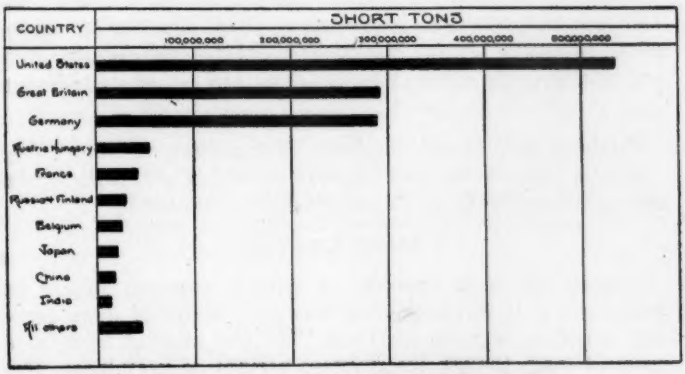


Figure 1. Production of Coal in Various Countries.

bers who are not themselves geologists or mining engineers. It is my plan to mention the important agencies engaged in investigation, and then to review the kind and scope of the various lines of work.

Among the important investigators may be mentioned those of the federal government, those of states, and those of private agencies.

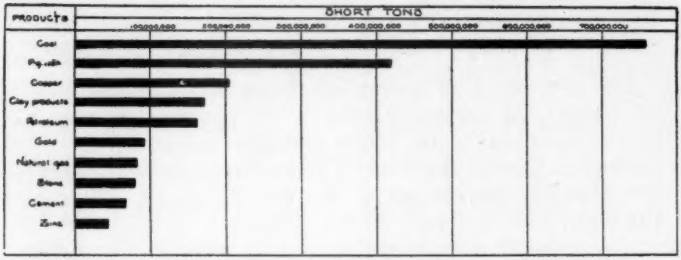


Figure 2. Relative value of United States Mineral Products.

FEDERAL BUREAUS

The U. S. Geological Survey was created in 1879 and has a record of service covering 34 years. During 1913 the work included geologic mapping in 45 states; topographic mapping in 26; stream gaging in 42; underground water studies in 19. Nearly 400 field men of the regular staff, besides numerous temporary assistants, were employed. The appropriations for the fiscal year exceed one and one-half million dollars.

As an off-shoot from the Geological Survey, the U. S. Bureau of Mines was created in 1910 to conduct investigations into safety and efficiency of the mineral industry. More than 150 technical men were employed in 1913. The Bureau maintained offices or laboratories in three cities outside Washington and operated six mine-safety stations and seven mine-rescue cars.

Another governmental office, the Bureau of Standards, conducts tests of clay and concrete materials, and investigates the use of electricity and other substances in mining.

STATE AGENCIES

Among the state agencies of mineral research should be mentioned first the geological surveys. Many of them came into existence between 1830 and 1840, and most of them have enjoyed long, though intermittent periods of usefulness. The present surveys range in age from 6 to 50 years and average

18 years. Three have existed more than 40 years, two others more than 30, and five others more than 20 years. The thirty-five state surveys were especially active during 1913, collecting and disseminating information intended to promote the orderly development of mineral resources. Several surveys also had responsibility in connection with highways, soils, forests, and reclamation of wet lands. Besides having these utilitarian functions, the surveys contributed notably to pure science. Altogether the state surveys expended approximately $475,000, and received the benefits of $140,000 additional expenditure by co-operating federal bureaus. About 100 scientists gave full-time service for the states, and about 50 others, besides topographers and soil experts, were furnished in co-operation.

To enumerate the mining schools or departments, and the experiment stations of the country would almost require a roll-call of States. But among the notable contributors to the profession may be mentioned Columbia, Yale, Michigan, Colorado, Minnesota, Missouri, and our new school at Illinois. These, together with the geological and chemical departments of our universities are producing the graduates who influence the mineral industry. The field and laboratory researches of these schools and colleges include real contributions to practical knowledge.

PRIVATE AGENCIES

Aside from official surveys, bureaus and educational institutions already presented, there are many private agencies of research and publication. An important work is done by professional and practical men who publish the accounts of their work in the dozen or more technical papers of the country. Mention should be made also of the research by great corporations which annually explore and drill mineral land. They either follow-up and utilize the results of official field work, or take the initiative themselves. The spectacular but fundamental work of the Carnegie geophysical laboratory has a practical bearing on problems of mineralization. Finally, a necessary forum of the mining business is provided by the American Institute of Mining Engineers, the American Mining Congress, and related organizations.

CHARACTER OF INVESTIGATIONS

A review of the character of investigations of mineral resources and industries includes, first, the early frontier ex-

plorations, then modern work. In this latter division are included topographic mapping, general geologic surveys, land classification, economic studies of particular minerals or substances, and technologic investigations.

The frontier explorations are described by Merrill,* from whom I quote freely.

The era of state surveys begins with the decade 1830-1839. During this interval scarcely a year passed but witnessed the establishment of a state survey or the organization of an exploring expedition, to which a geologist was attached. Thus were established surveys in Massachuetts in 1830; in Tennessee in 1831, Maryland in 1834, New Jersey, Connecticut and Virginia in 1835, Maine, New York, Ohio and Pennsylvania in 1836, Delaware, Indiana and Michigan in 1837, and in New Hampshire and Rhode Island in 1839. In addition, the United States Government for the first time recognized the practical utility of the geologist by authorizing the surveys by G. W. Featherstonhaugh of the elevated country between the Missouri and Red Rivers in 1834, and of the Coteau des Prairies in 1835; and by D. D. Owen of the mineral lands of Iowa, Wisconsin, and Illinois in 1839.

The fever for the state surveys, so prevalent during the first decade, seems to have quickly subsided, since during the following period, new surveys were established only in Alabama, South Carolina, and Vermont. Governmental surveys were also few, being limited to those by D. D. Owen in the Chippewa land district, and Jackson, Foster and Whitney in the Lake Superior region.

The cause of this sudden cessation is not quite apparent. It is possible, that the period of great financial depression beginning in 1836 may have had something to do with it. An important factor may have been the lack of geologists to agitate the subject and carry on the work, since nearly every man of prominence and experience was engaged in surveys and organizations already under way. The period was one of importance for results rather than for organization and preparation.

The single event of greatest consequence during this second decade was the appearance of the final reports of the New York survey. The volume of literature was naturally greater than at any previous period, since it included many of the reports of organizations of the previous decade, as those of Percival in

*Geo. P. Merrill, Contributions to history of American Geology; Annual report, Smithsonian Inst. 1904.

Connecticut, Booth in Delaware, Jackson in New Hampshire and Rhode Island, and Rogers in New Jersey. The establishment of a geological survey of Canada in 1841 should also be mentioned.

The financial depression, which proved so fatal to the state surveys during the second decade, 1840-1849, ran its course. Several new states had in the meantime been added to the Union, some of which showed commendable promptness in authorizing geological surveys. During the decade 1850-1859 new organizations were thus formed in fourteen states, eight of which had made no previous attempt. These eight, in alphabetical order, are California, Illinois, Iowa, Kentucky, Mississippi, Missouri, Texas, and Wisconsin. Six states for the second time undertook the work—Michigan, New Jersey, North and South Carolina, Tennessee, and Vermont. The National Government was also active, the most importat undertaking being the surveys in connection with the proposed Pacific railways. In addition to these, Capt. R. B. Marcy made a survey of the Red River region of Louisiana; Maj. W. H. Emroy, one of the Mexican boundary, and Colonel Pope one in the region of New Mexico along the thirty-second parallel. To each and all of these expeditions, geologists, or at least naturalists, were attached. The publication of by far the greatest importance of this third decade was, however, the long-delayed report of the Pennsylvania survey, which was truly epoch-making.

The following period, including the civil war, might naturally be expected to be one of uncertainty and inaction in matters relating to the sciences. With the passing of the war, active work has begun once more in states where it had been but temporarily suspended, and in others, new organizations were authorized, as in Kansas in 1864, Iowa and North Carolina in 1866, and Louisiana, Michigan, and Ohio in 1869.

The decade of the civil war brought to light a number of men for whom the piping times of peace, even when varied by Indian outbreaks in the West, afforded insufficient opportunities. They were men in whom the times had developed a power of organization and command. They were, moreover, men of courage to the point of daring. It was but natural, therefore, particularly when the necessity for military routes in the west and public land questions were taken into consideration, that such should turn their attention toward western exploration. Further, the surveys made in the third decade, in connection with routes for the Pacific railroads, and the

work done by Evans, Hayden and Meek in the Bad Lands of the Missouri, had whetted the desires of numerous investigators. Willing workers were abundant during the fourth decade, 1870-79, and Congress not difficult to persuade into granting the necessary funds. Hence expedition after expedition was organized and sent out, some purely military, some military and geographic, with geology only incidental, and others for the avowed purpose of geological research.

Under such conditions was inaugurated the work which culminated, in 1879, in the organization of the present U. S. Geological Survey, which, for breadth of scope and financial resources, is without counterpart in the world's history of science.

The more important of the expeditions above referred to were Hayden's Geological Surveys of the Territories; King's Geological Survey of the Fortieth Parallel; Powell's Surveys of the Grand Canyon of the Colorado and adjacent regions; and Wheeler's Geographical Surveys West of the One-hundredth Meridian.

It is possible only to mention the organizations of these four decades and it is necessary to omit the results of the work, except to say that the knowledge of the mineral resources of the States and territories was extended rapidly and made a matter of public record by the frontier explorations. Much of the work of the early 50's was wonderfully well done.

LATER INVESTIGATIONS

Topographic mapping is of great value as a basis for study of mineral resources. While at least three states have made such surveys systematically, the U.S. Geological Survey has executed nearly all topographical surveys now available to the public. The total surveyed to date equals 40 per cent of the country. In this work about twenty states co-operate and furnish half of the necessary funds. Practically $600,000 was spent for public topographic surveys in the United States during the fiscal year 1913. More than 22,500 sq. mi. (one half of Illinois) was actually surveyed. The total surveyed to date equals 40 per cent of the country.

General geological surveys of specific areas have been the approved type for public and corporation work, and maps, (Figure 3) and reports based on states, counties, quadrangles, or other units have aimed to portray the kinds and relations of all the exposed formations and to present the facts relating

Figure 3. Distribution of Petroleum and Natural Gas Fields in the United States. After Day, U. S. Geological Survey.

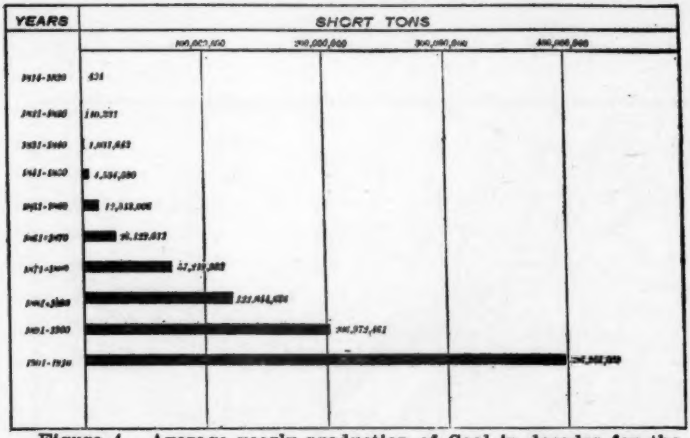


Figure 4. Average yearly production of Coal in decades for the United States.

to all mineral resources, including soils and waters. This is perhaps logical in frontier areas of slight development.

Most of the states have been mapped, at least in reconnaissance by local bureaus, though detailed work after modern standards has been completed only for states of small area, or for small fractions of the larger states. The U. S. Geological Survey work has spread over much of the country as shown by figure 4.

Classification of public land by the U. S. Geological Survey has become an important division of work. The purpose is to determine whether certain lands sought to be acquired from the Government are of the character contemplated by the statute under which they are sought. Large withdrawals from entry of public lands during several years, have been made by the President or by the General Land Office, pending classification of the land as to its mineral character.

The Land Classification Board of the Survey, comprises eleven geologists and engineers, and twenty-three others of minor grade. The work is done by sections devoted to the following subjects: Coal, oil, phosphate, metallic ores, water power and irrigation. The basis of classification and valuation of coal land is logical and depends chiefly on the thickness, depth, and heat value of the coal. Phosphate beds containing less than 30 per cent of tricalcium phosphate are considered to be non-mineral. Beds containing 70 per cent or more, and measuring 6 feet or more in thickness, are reserved to a depth of 5,000 feet. Intermediate grades are reserved to lesser depths.

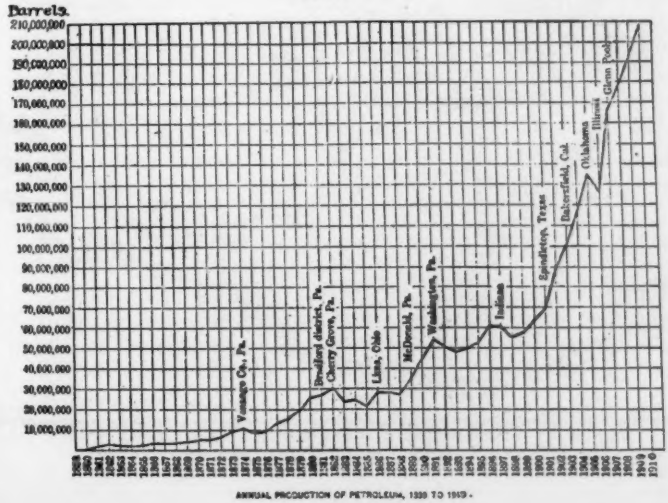
During 1913, more than 2,000,000 acres of coal land were classified, and valued at nearly 33½ million dollars, while nearly 8,000,000 acres were classified as non-coal land. To date the classifications include 19,000,000 acres of coal land, 61,000,000 non-coal land. There is awaiting classification the following lands, expressed in acres:

Coal—58,000,000; oil 4,600,000; phosphate, 3,000,000; potash, 130,000.

Besides this federal classification work several states, notably Michigan, Minnesota and Wisconsin, delegate similar work to their geological surveys in co-operation with their tax commissions. All mineral lands are to be classified as a basis for taxation. In Wisconsin, during 1913, nine field parties were engaged in making magnetic surveys to determine the iron-bearing lands not yet under development.

Recently investigations of particular minerals or substances are perhaps occupying a more important position than general areal surveys. Reports on coal, oil, iron, clay, phosphate, platinum, etc., of various states or smaller areas, have been issued by public or private investigators and have been of great practical use to the mineral industries. Numerous specialists in particular lines of work have developed and have largely superseded the general geologist and mining engineer of all-around work. This has come about largely because of the increased utilitarian functions of the work, but even in its pure-science aspects a high degree of specialization has evolved. The distribution of important resources is shown by figures 5 and 6.

Figure 5



ANNUAL PRODUCTION OF PETROLEUM, 1859 TO 1913.

Figure 6. Distribution of Coal Fields in the United States. After Campbell and Parker, United States Geological Survey.

The statistical work of the U. S. Geological Survey is carried on under the direction of twenty or more geologists who have become expert in regard to special mineral industries. Over 62,000 operators report annually the details of their production, but this report is supplemented by personal visits of experts to significant operations in all mineral lines.

Specialization in study of water resources is now common throughout the country. The U. S. Geological Survey maintains twelve district offices in the country and records the stream measurements from over 1100 stations. It also has experts in underground-water studies. A series of reports on this subject for the entire coastal-plain region of the Atlantic and Gulf states has been completed.

Among the subjects covered by the state surveys from year to year may be mentioned those of the 1913 program, as typical. Reports were issued by various states on: Building stone, cement materials, agricultural limestone and marl; stone and gravel for highways, concrete and ballast; clay, shale and fire-clay; asbestos, soapstone, feldspar; salt, gypsum, glass-sand, lithia, rock-phosphate; coal, lignite, peat, petroleum, gas; precious metals, iron, lead, zinc, copper; underground and surface waters.

TECHNOLOGIC STUDIES

Finally a view of investigations of the mineral industries would be incomplete without consideration of *technologic studies*. These are doubtless in progress in innumerable lines by chemists, metallurgists, and engineers employed by corporations and other interests, and the resulting increased efficiency in recovery and utilization of mineral products, and in safety of employes is truly remarkable. Among the lines of public investigation and experiment by the U. S. Bureau of Mines, by various mining schools, and by the state surveys should be mentioned the following:

Increased safety and efficiency in mine timbering, ventilation, hoisting, and in use of explosives and electricity; elimination of explosions due to gas and to coal dust; perfection of processes for by-product coking, briquetting, and for gas-producer operation; recovery of low-grade ores and of colloidal slimes, and other milling wastes; smelting of refractory ores and recovery of waste gases; practical tests of clay materials for extended uses; checking wastes of natural gas and extending the life of oil fields by preventing refrigeration and precipitation in the sands, and by controlling movements of water in the sands.

Truly, the investigation of the mineral resources and industry of the country covers a magnificent field of the highest importance to the nation's life and prosperity. Considering the brief span of years already employed, the knowledge of distribution, character, and utilization of our mineral wealth is surprising. Furthermore, when it is remembered that the most rapid contributions to knowledge and most extensive development in operations have come during the last fifty or even thirty years, the promise for increased efficiency and scientific development and management in the near future is exceedingly bright.

RIGIDITY AND VISCOSITY OF THE EARTH, AND THE BEHAVIOR OF SUBSTANCES UNDER STRESS

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The experiments recently conducted at the Yerkes Observatory for the purpose of ascertaining the action of the mass of the earth in yielding to the gravitation forces of the sun and the moon, gave the result that the earth acts like a solid body with an elastic coefficient of the order of that of steel—and with a coefficient of viscosity which is very high—probably also of the same order as that of steel.

For detailed account of these experiments, see Journal of Geology, Vol. XXII, No. 2, 1914.

From the known increase of temperature as we go below the surface of the earth, it follows that the temperature of the interior must be very high—high enough to melt almost if not quite all known substances under normal conditions.

It follows that the enormous gravitational pressure which the mass of the earth experiences is sufficient to prevent this fluid condition—in other words, that pressure increases elastic rigidity as well as viscosity.

An attempt was made to detect such an effect, using the relatively small pressures obtainable in the laboratory (of the order of 50,000 pounds per square inch) and the results obtained clearly confirmed this conclusion. However, certain rather curious and baffling anomalies presented themselves which made the results less conclusive than was anticipated.

The study of these anomalies has been in progress for several months and an account of the results will probably be published as soon as the information obtained is available.

At present it may be stated provisionally that the laws governing the behavior of substances under stress are the following:

First—There is a rapid elastic yield, which, if inertia be negligible, is practically instantaneous.

Second—This is followed by a slower yielding which diminishes with the time and ultimately attains a constant value which may be zero.

Third—If the stress is released the specimen returns almost instantly to a point short of its original position.

Fifth—The behavior depends, in many cases, on the previous stresses to which the specimen has been subjected—these usually tending to strengthen the specimen.

These experimental results are to be accounted for on theoretical grounds and considerable progress has been made in this direction.

THE INTERNATIONAL PHYTOGEOGRAPHICAL EXCURSION

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In the summer of 1911, there was organized in the British Isles under the auspices of the British botanists, the first International Phytogeographical Excursion. This was so successful in getting plant geographers from various countries together for the purpose of discussion in the field that it was unanimously decided to have a similar excursion in the United States in 1913. The 1913 excursion started at New York on July 26th, and closed at the same city on October 5th. The general route of the excursion included the following places: Niagara Falls, Chicago and the neighboring sand dunes; Lincoln, Akron, Colorado, Colorado Springs, Pikes Peak, Salt Lake City, North Yakima, Tacoma, Mt. Rainier, Crater Lake, San Francisco, Mt. Tamalpais, Yosemite, Carmel and Cypress Point, Salton Sea, Tucson, the Santa Catalina mountains, and New Orleans.

The excursion numbered from twelve to fifty, depending upon the number of American participants at various places. Ten European members were present at most all of the points visited. Among others, these Europeans included such well-known plant geographers as Professor Engler of Berlin; Professor Schroter of Zurich, and Mr. Tansley of Cambridge. Professor von Tubeuf, the famous student of trees and their diseases, was also a member of the party.

Nearly all of the great American types of vegetation were visited and studied, numerous photographs being taken and numerous plant specimens being collected. Professor Henry C. Cowles of the University of Chicago had general charge of the excursion, but was ably assisted by Professor Frederick E. Clements of the University of Minnesota; Dr. George E. Nichols of Yale University, Dr. George D. Fuller of the University of Chicago, and Dr. Alfred Dachnowski of Ohio State University, as well as by large numbers of botanists at the places visited.

RECENT THEORIES OF FERTILIZATION AND PARTHENOGENESIS

BY FRANK R. LILLIE, UNIVERSITY OF CHICAGO

Two main problems of fertilization stand in the foreground of all recent work viz: the problem of the initiation of development and the problem of bi-parental inheritance. The latter problem has received a much more complete and satisfactory analysis than the former which is alone under consideration in the present paper. The problem may be stated thus: Why is the unfertilized egg usually incapable of development? And how does the spermatozoon initiate the developmental processes?

This problem was naturally conceived in the early part of the modern period (1875 to the present) in morphological terms; and Boveri's theory that the egg did not develop because it lacked the "organ of cell-division" (viz: the centrosome) and that the spermatozoon enabled it to develop by supplying the missing organ was long held by most naturalists. But with the advent of physiological analysis of cell life the inadequacy of this point of view soon made itself felt. The discovery of artificial parthenogenesis by Loeb started a new era in this problem. It was shown that the role of the spermatozoon could be dispensed with in initiation of development, and that a change in the chemical constitution of the medium could take its place. In such a case it was obvious that no new cell organ was needed by the egg. Following this epoch-making discovery a great many investigators studied the problem of initiation of development in the eggs of various species of animals, with the result that a great variety of agents was shown to be effective in the production of parthenogenesis in different forms. These can be classified under the head of chemical agents, osmotic changes, temperature changes, radiation, mechanical shock and pricking. In

fact a very considerable proportion of the agents effective in stimulating protoplasm may be efficient agents in inciting parthenogenesis in one or another variety of eggs. It has been argued that, if it were possible to find the common factor of all efficient parthenogenetic agents, the cause of the initiation of development would be found. This attempt has not, however, led to a satisfactory explanation; and it may be doubted whether such a form of analysis would lead to any more satisfactory results in the case of initiation of development than in the initiation and propagation of a nerve impulse, which may be equally well started by a similar set of external changes.

Moreover, while it is obvious that in parthenogenesis, part of mechanism of fertilization must be employed, we need not necessarily gain any direct knowledge of the true fertilization reaction between ovum and spermatozoon. In fact if we were to accept any theory of parthenogenesis we would still be far from understanding many of the phenomena of fertilization associated with initiation of development.

On any such basis (1) We do not understand the nature of the immediate reaction between the ovum and spermatozoon in fertilization; (2) We do not understand the nature of the reaction of the sperm nucleus in the interior of the ovum; (3) We do not understand why fertilized ova become non-fertilizable; (4) Why immature ova are non-fertilizable; (5) We do not understand the variations of affinity within a species, leading to almost absolute sterility in self-fertilization in some cases, or between the members of certain varieties in other cases; (6) We do not understand either the sterility or fertility of different species when bred together.

Not only are these unsolved problems, but we have only the slightest experimental basis for their solution by methods of parthenogenesis. A vague conception that the solution of such problems must lie in the field of chemistry has been entertained, but without any experimental basis whatever until very recently, and that of a slight character.

If these things are true the defect must lie in the methods of investigation because some of the most brilliant students of biology have been concerned with the problems of fertilization. The defect in the methods of artificial parthenogenesis is obvious, because it consciously restricts the field of investigation. Nothing less than an analysis of the process of fertilization itself can give a rounded theory of fertilization. The study of merogeny, of hybrid fertilization, of partial fertiliza-

tion, of self-fertilization, of the antagonistic action of sperm suspensions of different phyla, of the fertilizing effect of injured spermatozoa, etc., are methods that have recently been employed for the direct analysis of fertilization, and which have aided greatly in the definition of problems, though but little in their solution.

I have therefore attempted for some years to make a direct analysis of the fertilization problem, and have developed two new methods of analysis: (1) The use of sperm-suspensions as indicators of reactions. (2) The study of fertilization by inhibitors.

The first method was suggested by the fact that many of the most delicate of biological reactions are determined by the use of living cells as indicators. In the field of immunology no other indicators are known for bodies concerned in such reactions in many cases. The sperm cells of a species might be expected to serve as indicator of substances formed by the egg with which reaction normally takes place in fertilization. As regards the second method, it is obvious that an analysis of the reaction concerned in fertilization might be attempted by agents which would hinder the normal course of events at any place. This would constitute a method of analysis by which the total reaction might be broken up into its elements.

I. *Results from the Use of the Sperm Suspensions as Indicators.*

If some of the sea-water from a suspension of eggs of Arbacia be added to a milky suspension of the sperm of the same species in sea-water, a very rapid agglutination is obvious to the naked eye, resulting in the formation of detached white masses of agglutinated spermatozoa, leaving the fluid more or less clear, depending on the strength of the reaction, In a few minutes the agglutinated masses break up into their constituent elements and the suspension becomes milky again. The reaction cannot be repeated in the case of the sperm suspension, if it is incomplete in the first instance. In chemical terms it cannot be repeated after saturation. The spermatozoa, however, retain their vitality. We have then a combination of some elements of the spermatozoa with a secretion from the ripe ova, which so alters the physical character of the sperm cells that they adhere in masses. The reaction in question is without prejudice to the life of the spermatozoa.

The agglutinating substance is produced only by ripe eggs of Arbacia, and not by immature eggs or by any other tissue of the species; in other words, only fertilizable eggs produce it.

The substance is more of less specific in as much as it will not agglutinate the spermatozoa of Nereis for instance. Professor Loeb has since been able to determine a higher degree of specificity, as between related species of sea-urchins

It is possible to study the production of this substance quantitatively, that is to say, a given bulk of ripe eggs may be shown to charge a given amount of sea-water to an extent that may be measured in the following way: The agglutination as noted, is reversible. It is therefore possible to establish a minimum reaction as unit in which reversal takes place in four to five seconds. Then the amount of dilution of a given agglutinating solution necessary to reduce it to unit strength is a measure of concentration of the agglutinating substance.

To give an idea of the quantities involved it may be stated that sea-water which has stood over one quarter its bulk of ripe eggs for half an hour may be capable of 1/800 to 1/3200 dilution, or is of the strength of 800 to 3200 agglutinating units. By another method we may ascertain that a single c.c. of the eggs placed in 8000 c.c. of sea-water will charge the whole body of sea-water with sufficient quantity of the agglutinating substance to be detected. The unfertilized ripe eggs of Arbacia produce this substance as long as they live and remain in a fertilizable condition; they may be washed repeatedly in sea-water, and when restored to fresh sea-water this is soon found to be charged with the substance in question. In certain experiments I have carried out thirty-five successive washings of a given lot of eggs during a period of three days without being able entirely to dispose of the agglutinating substance.

Definite quantitive relations in the reaction with the sperm suspension may also be estimated by the number of units of the agglutinating substance which can be neutralized by a given standard suspension of the spermatozoa. For the details, I must refer to previous papers.

On account of the activity of the eggs in producing this substance and the avidity of the sperm for it, it seems reasonable to assume that it plays some part in the normal fertilization reaction.

It was therefore interesting to find that the eggs contain a substance, which they do not normally secrete, which neutralizes the sperm-agglutinating action of the egg-secretion,

*These observations must be made under the microscope: a quantity of sperm suspension is mounted on a slide under a raised cover slip, and a drop of the fluid to be tested is injected into the suspension by means of a capillary pipette.

i. e., which renders the combination of the sperm with the agglutinating substance impossible. The presence of this substance may be demonstrated by methods that plasmolyze the egg or extract its internal substances. If for instance, eggs are deprived of the jelly in which they are normally embedded, and which is heavily charged with agglutinating substance, in order to get rid of excess of the agglutinating substance, and are then divided into two equal lots, one of which is placed in a certain quantity of sea-water, and the other in an equal bulk of distilled water, it is found that plasmolysis takes place in the distilled water, and internal substances are extracted from the egg. The supernatant fluid from the distilled water is at first more highly agglutinative than the sea-water, which contains only the normal secretion of the eggs. But there is present in the distilled water extract, a substance which tends to inhibit agglutination, and in a short period of time distilled water extract becomes entirely neutral. This is not merely an effect of distilled water on the agglutinating substance, because the latter may be kept for a long period of time in distilled water without deteriorating, but it is due to the presence of a body which actually destroys the agglutinating substance, or combines with it, in such a way as to prevent its effect.

These results suggest that in normal fertilization the combination between the agglutinating substance and the spermatozoon is essential, and that polyspermy is prevented by a neutralization reaction between the two substances produced by the eggs. I have therefore proposed the term *fertilizin* for the sperm agglutinating substance, and *anti-fertilizin* for the other.

It would follow that eggs in which the fertilizin is removed by any method should be incapable of fertilization. While it has proved extremely difficult to completely dispose of the fertilizin content of eggs, and to test this conclusion, it has nevertheless been possible by repeated washings greatly to reduce the fertilization content of eggs and secure the demonstration that the capacity for fertilization is correspondingly reduced.

Eggs when once fertilized are incapable of fertilization, that is to say the protoplasm of such eggs will no longer react with the spermatozoa. Such eggs should therefore *ex-hypothese,* be devoid of fertilizin content and this is the case.

To sum up: It is shown that ripe unfertilized eggs of Arbacia secrete a substance which produces a more or less specific agglutination reaction with sperm of the same species. Before acquiring this substance, *i. e.,* before ripening, the eggs

are incapable of fertilization; after it is lost, whether by washing or preceding fertilization, the capacity for fertilization is also lost. We therefore conclude that the agglutinating substance is necessary to fertilization.

II. *Use of Inhibitors.*

1. Inhibitors in blood.

It is a fact well known to Embryologists, but hitherto not studied in any systematic fashion, that the plasma of blood or tissue secretions of the species tends to hinder the fertilization reaction.

I have made a somewhat detailed study of this phenomenon in the case of the Sea-Urchin, Arbacia punctulata, the detailed results of which are published in volume 16, of the Journal of Experimental Zoology. Here it may suffice to say that the addition of filtered serum of Arbacia blood to the sea-water in which insemination is to be performed, strongly inhibits fertilization. If a series of blood solutions containing, let us say 10, 20, 30, 40 per cent, etc., up to 100 per cent blood be prepared and equal quantities of ova inseminated with equal quantities of spermatozoa in each member of the series, the per cent of fertilization will usually run from about 100 per cent in fertilization control to zero in the undiluted blood serum. All the sperm are living and active in each member of the series.

The inhibition by the blood is not due to direct harmful action on either reproductive element alone for either eggs or spermatozoa may be exposed to the action of such solutions and after washing be found to possess good capacity for fertilization. It might be supposed that the inhibitor acts like the anti-fertilizin by preventing union between fertilizin and spermatozoa. This is, however, not the case because of a solution of fertilizin in blood is as effective in agglutinating spermatozoa as a similar solution in sea-water.

A second hypothesis would be that the inhibitor might act on a second side-chain of the fertilizin which is active in fertilization by combining with certain constituents of the ovum. If this is the case it would follow that the inhibitor in the blood could be neutralized by first saturating it with fertilizin from other eggs and this is found to be the case: If a given sample of blood be divided into equal parts of which one is saturated by fertilizin from unfertilized eggs, and inseminations be made in graded series of both, the usual inhibition reaction will be found in the first series, but is entirely absent in the second series.

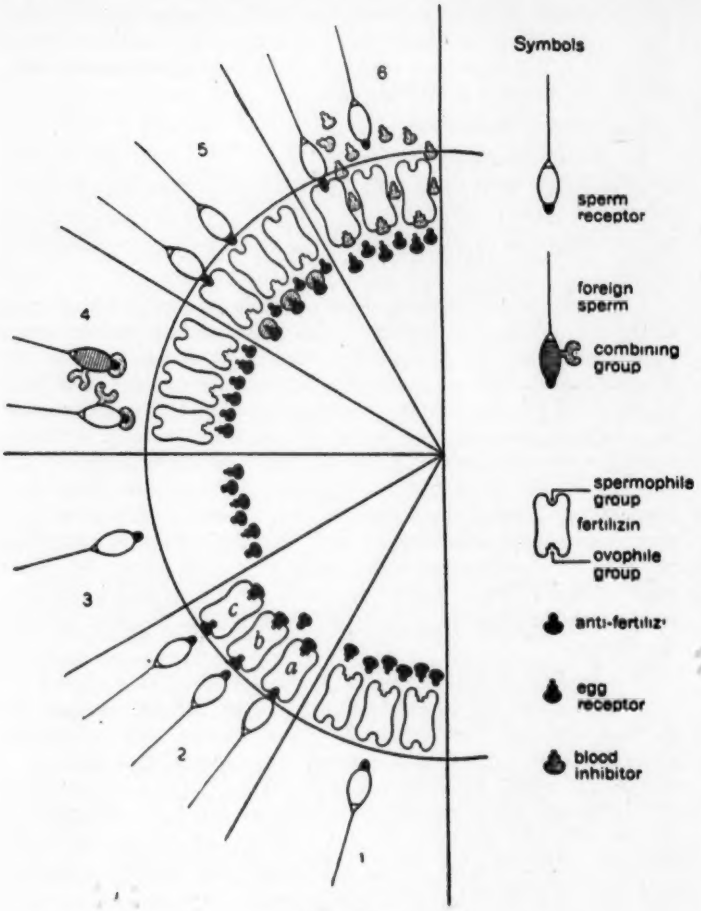

Figure 1

DESCRIPTION OF FIGURE

Fig. 1. In successive sectors of the egg there are represented the mechanism of fertilization and the blocks to the mechanism, as follows:

Sector 1. The arrangement of substances in the unfertilized egg and in the spermatozoon that are active in fertilization. See explanation of symbols.

Sector 2. The mechanism of normal fertilization. The sperm receptor unites with the spermophile group of the fertilizin and the egg-receptors with the ovophile group of the fertilizin owing to activation of the latter by the sperm (a). Molecules of the anti-

fertilizin combine with the spermophile group of the adjacent fertilizin (b and c) and thus block the way for supernumerary spermatozoa. This is the postulated mechanism for prevention of polyspermy. At the same time molecules b and c of the fertilizin have also united with the egg receptors.

Sector 3. Inhibition of fertilization by loss of the active body, fertilizin.

Sector 4. Theory of antagonistic action of spermatozoa of different phyla. The sperm receptors are occupied by combining groups cast off by the antagonistic spermatozoa.

Sector 5. Fertilization is blocked by occupancy of the egg-receptors. Purely hypothetical.

Sector 6. Theory of inhibitory action of blood of the same species. The ovophile group of the fertilizin is occupied by molecule in the blood (inhibitor) possessing the same combining group as the egg receptors. Molecules of the blood inhibitor also shown in the medium.

The fertilizin is represented in the diagram as occurring only in the cortex of the egg. But it also occurs in high concentration in the jelly surrounding the egg. The spermatozoon must thus normally arrive at the egg-membrane loaded with combined fertilizin. This fact, however, makes no essential difference in the theory, and its representation would complicate the diagram.

We therefore came to the conclusion that the substance which we have been calling fertilizin is the active agent in fertilization. That it possesses two side chains, one of which is spermophile, combining with certain elements of the spermatozoon (sperm receptors), the other of which (the ovophile) combines with certain elements in the egg (egg receptors). Fertilization is therefore not a two-body but a three-body reaction. Of these one is carried by the spermatozoon, the sperm receptors, and one by the egg, the egg receptors. The third, (fertilizin) is produced by the egg and reacts with both the others. The essential reaction in fertilization must be regarded as that of the fertilizin with the egg receptors; and the spermatozoon must be regarded as playing the secondary role of activator. In parthenogenesis the active body is still the fertilizin, and the various parthenogenetic agents, in this case play the role of activators. Thus parthenogenesis and fertilization may be regarded under one point of view.

The diagram represents the foregoing theory with the aid of symbols. Sector one illustrates the relation of the side chains before fertilization. Sector two illustrates normal fertilization. Some of the consequences of the theory are indicated as follows:

1. (Sector 3). If the egg loses its fertilizin it cannot be fertilized. This we have already seen.

2. (Sector 4). If the sperm-receptors are occupied, the spermatozoa cannot fertilize. The *Godlewski phenemenon* (Antagonism of sperm suspensions.)

3. (Sector 5). If the egg receptors are occupied, fertilization cannot take place. *Purely Hypothetical.*

4. (Sector 6). If the ovophile side-chain of the fertilizin be occupied, fertilization cannot take place. *Inhibiting action of blood.*

5. (Sector 2, b and c). If the spermophile side-chain be occupied, fertilization cannot take place. *Action of anti-fertilizin; prevention of polyspermy.*

It is obvious that these five blocks are purely chemical in their conception, but the possibility of other blocks in the fertilization reaction must not only be conceded, but strongly emphasized; as the essential reaction takes place across the egg membrane, the condition of this membrane, whether permeable or impermeable, is an essential factor in the reaction. The reaction must also be subject to the usual environmental conditions of comparable bio-chemic phenomena, such as temperature, ionic constitution of the medium, etc. Modification of these conditions will determine the occurence or non-occurrence of the fertilization reaction.

This theory transfers the fertilizing power from some hypothetical substance contained in the spermatozoon to a definite substance contained in the egg itself, in relation to which the sperm acts merely as an activator. It is therefore radically opposed to the theory that the sperm carries a lysin or other substance that acts directly on the cortical layer of the egg.

The mechanism which we have been considering concerns the cortical changes in the egg. The question therefore arises, whether the second phase of fertilization which I have shown previously to be dependent on the penetration of the spermatozoon, is likewise a three-body reaction, and if so whether the fertilizin is the intermediate body in this case also? This is a problem that I have not yet fully worked out, but the indications are for a positive answer to both these questions. There are a number of facts of considerable interest in this connection. (1) As is well known for Arbacia, spermatozoa may penetrate ovocytes but without fertilizing them; In Chaetopterus I have observed the same fact. (2) If the cortical changes are induced mechanically or chemically in the egg of Nereis, there is a stage where the spermatozoa may still penetrate but without causing complete fertilization. Miss Allyn demonstrated the same facts for Chaetopterus. (3) Dr. Kite

observed that the injection of from 3 to 20 spermatozoa into the interior of the egg of Asterias with a microscopic capillary pipette does not result in any fertilization reaction. These facts indicate that when spermatozoa penetrate before the formation of fertilizin (ovocytes) or after its fixation (Nereis and Chaetopterus), or without the opportunity of reacting with the fertilizin (Dr. Kite's experiment) fertilization fails.

In these experiments we have egg and sperm in most intimate relations, but apparently incapable of reacting in the absence of an intermediate body, which appears to be the same body, viz: the fertilizin, through the mediation of which the cortical changes are induced.

In serum physiology, we have become familiar with many reactions for which living cells alone are adequate indicators; such are agglutination, cytolysis, opsonic reactions and anaphylaxis; the bodies concerned in such reactions viz: agglutinins, cytolysins, opsonins, etc., are not known directly, but only by the use of cell indicators. Their chemical nature is entirely unknown, but they are so definitely known through cell indicators, and so controlable, that many quantitative procedures of the most delicate character, in immunology, are based on this knowledge. The cells themselves are the source of such bodies, yet the site of their cellular origin is unknown, and their roles in normal cell physiology are problematical.

The ordinary chemical analysis of the cell begins by destruction of its more highly organized living constituents; it is obvious that such methods are inadequate for the investigation of the immediate reactions in living protoplasm.

The results of these experiments may then gain a still broader interest if they be taken to indicate a method for the study of such reactions.

THE MOVEMENT TOWARD A UNIFIED SCIENCE COURSE IN SECONDARY SCHOOLS

BY HAROLD B. SHINN, CARL SCHURZ HIGH SCHOOL, CHICAGO

The title of this report, as announced, is the result of careful editorial work on some one's part and we would correct it immediately. It would appear that there can be no real "Unified Science Course" as long as localities and their needs are different, or as long as men's minds are individual and various. Your attention is asked for only a brief statement of the current movement toward a unified science course.

Our science courses in college and high school have passed through just as distinct phases as have the development of the microscope and automobile. At the time of Linnaeus's first connection with the University of Upsala there was a marked movement there toward field work in natural history which so upset the equilibrium of the institution that Linnaeus was forced to resign. Attendant upon the development of the microscope was an awakening in microscopic technique. Modern research in the higher sciences has brought into the text books and our teaching a mass of material much of which, after trial, proves too heavy for the mind of the high school pupil. This seems to be the climax of specialization in high school science. Hitherto we have been most interested in the proper presentation of our subjects in all their fullness and beauty; the development of the child or the man has been quite incidental.

"Certain defects of science courses in content and in methods are becoming increasingly apparent. In some respects science teaching is not as closely related to the environment and experience of the pupil today as it was a quarter century ago. With the elaboration of apparatus and the increased attention to quantitative methods, there has come an aloofness from the experience of everyday life, so that the pupil may secure a high standing in physics, chemistry, biology without necessarily gaining an understanding of their applications. Moreover, teachers in science in some instances over-emphasize the importance of formal and fixed procedure and, as a result, are not alert to utilize new opportunities."

The reaction now is toward making each subject valuable and interesting to the pupil, and toward a closer articulation of the subjects as opposed to their former isolation and individualness. Courses are being compiled and fitted, being cut down here and built out there, the high places made low and the valleys filled, in order that classes may be held through the course.

The Commissioner of Education in the report for 1910 brings out the potent fact that at the then existing rate of decline, physiology will cease to be studied by 1925, physics by 1935, chemistry by 1945, and physical geography by 1960. While these statements seem overdrawn, yet they do emphasize the inefficiency of our past methods of presenting our sciences and their suicidal effect.

Without entering into the lengthy discussion of conditions which we all appreciate, may we turn to the immediate topic. Within the last decade there has sprung up a great dissatis-

faction with the conventional courses. This is particularly true of the teachers in the lower years of the high school, for it is they who see the enormous loss in attendance and in interest in school work. In 1892 a committee of the National Educational Association recommended the elaboration or intensification of the first year science, geography. Gradually this became too intensive and too collegiate. In 1909, seventeen years later and five years ago, geographers inaugurated a movement among themselves to react against the inattention to human response and environment, the fitting of pupils for college rather than for life, and the suppression of interest in economic or industrial facts and factors.

Apparently thus far science teachers generally have been quite willing for the first year teachers to wrestle alone with the task of revision and adaptation. In fact the others have been eager to prune back geography to almost nothing and to graft on scions of almost everything else. But they insist that their own courses, as biology, chemistry, or what not, be left inviolate and intact.

At the present time, however, a very widespread movement is at work toward the revision of the entire high school course, science included. This work is partly under the direction of the National Educational Association and its committee on the reorganization of high school education. Its purpose and plans are given in Bulletin No. 41, 1913, of the United States Bureau of Education. This general committee presides over ten subcommittees or the high school departments: the subcommittee on natural science is divided into five others for (1) First Year Science; (2) Physics; (3) Chemistry; (4) Geography, and (5) Biology. The special committee on biology immediately upon its appointment broke up into many minor groups in order that all sections of the United States might he represented and at work. The special committee centering in Chicago, of which the speaker has the honor to be a member, includes representation from Wisconsin, Michigan, Indiana and Illinois.

It is the plan to continue this work for a period of years but to change the membership several times in order that the final report may be the work of many men and that it may be carefully formulated and revised; its first report may be collated in 1915. The general revisory committee hopes that it will:

"(a) Formulate statements of the valid aims, efficient methods and kinds of material whereby each subject may best serve the needs of high-school pupils.

"(b) Enable inexperienced teachers to secure at the outset a correct point of view.

"(c) Place the needs of the high school before all agencies that are training teachers for positions in high schools.

"(d) Secure college entrance recognition for courses that meet actual needs of high school pupils."

From this statement of aims the welding of the several sciences into a unified course is not, apparently, a definite and immediate purpose. Whether this result ensues is a question.

To our personal knowledge there is no other broad movement looking toward the reorganization of secondary education, although departmental sections throughout the country are engaged thereon. Notable among these is the Central Association of Science and Mathematics Teachers, a committee of which is at present working up a two year course in general science. Its preliminary report, which was presented at the Des Moines meeting last Thanksgiving, stated in a very general way the aims in this two year "stem" course. A successful "stem" course in general science has been worked out by W. K. Eikenberry of the School of Education, University of Chicago; it was adopted by the Agricultural Section of the Illinois High School Conference last November and is outlined in the current (January) issue of *School Science and Mathematics.*

From the accounting of the plans of the National Educational Association and of the Central Association of Science and Mathematics Teachers, and that of other isolated cases, it appears that with the possible exception of this Illinois Academy of Science, no organization has yet considered the formulation of a general course in high school science in which there shall be not only a unity or commonness of purpose and method, but even more, a close articulation or, to put it more plainly, an almost entire absence of demarcation between the natural sciences.

As heretofore given, physiology, botany, chemistry, and others have been taught and studied as independent units. When several of these sciences were in a course there was a strong staccato effect, a marked hiatus between them and a full stop at the end of each study; often there were many of these within the subject. Thus while a so-called science course was listed the pupil studied only separate units, units just as separate and distinct as Latin and history, as mathematics and English. The broad scientific truths or generalizations prob-

ably dawned upon the pupil's comprehension, if at all, long after high school days were over. The causes of this lack of articulation were at least two: the teacher and the text-book.

There exists in the minds of certain members of this committee, as probably has been stated at a previous meeting, a very admirable conception of a high school science teaching which will break down and clear away the barriers which have been the jealous boundaries of each man's domain;which will interweave the materials, the methods, and the facts of all the sciences into a fabric so smooth that a pupil entering upon the science course of a curriculum will find less difficulty in beginning new subjects each year and hence will be more apt to complete the entire course. Such a course has been well marked out in English. English now is a four-year unit and no longer solitary, independent units; the course is working excellently. In such a course the materials and information from one laboratory will be utilized in the others. The chemical, physical, biological, and geographical materials will be unified.

For example: A zoology or physiology class, when studying the animal eye, will begin with a simple lens, determination of principle and secondary foci, and image formation, and from this physical basis work into the use of a retina. This material used again in the physics laboratory, will give point or application to a cold law of optics or refraction.

And throughout the course materials of study will be interchanged and utilized until the pupil realizes that no phenomenon is to itself alone, but that all unite to make the whole. In such a course it may even come about that instead of the name plates on laboratory doors and in catalogs being called "Chemistry," or "Geography," they will be "Third Year Science," and "First Year Science."

In conclusion, then, may it be stated that by "unified science" is not meant a uniform, standardized, "cut and dried" course for all teachers, all classes and all localities, but a science the parts of which are not integers but fractions, not isolated subjects taught by trained specialists, but are portions of a broad (or deep) subject, science, taught by men who specialize in the general education of youth.

AN ANALYSIS OF SOME TEXT BOOKS IN ZOOLOGY

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In a questionaire which was sent out something over a year ago to a number of the high schools of the middle west, an inquiry was made as to the title of the text book, which is being used in the high school course in zoology. Returns indicate that there is a surprising variation in the book adopted. It is true that one text was used predominantly, yet a great many were found in use and several of these were texts of the older type, dating their publication back forty years or more. This suggested an attempt at an analysis of the various texts in zoology. With the aid of a class of graduate students, some thirty text books were analyzed. It was evident as the analysis proceeded and the results were tabulated, that the textbooks in use during the history of zoology instruction in this country indicate in the main, the changing conceptions of relative values in the instruction. It would be beyond the limits of this paper to undertake to present all of the data, so certain texts are selected from the lot analyzed which will be representative of the various types of zoology instruction which have been in vogue, and which will show, in a measure at least, the tendencies which are now at work in the instruction in high school zoology.

These figures will in no case foot up a total of 100 per cent because the topics selected are only representative ones from the group of some twenty-five topics that make up the complete analysis of the several books. The methods of getting at the figures were as follows: The book was read, and an estimate made, of the number of pages or fractions of a page (estimated in lines) devoted to each subject. Frequently, therefore, several subjects might be considered upon the same page, and these subjects might re-appear at many points in the course of the book. A summation of the pages and fractions of a page was finally made for each of the several topics and the percentage was computed which this total made of the entire number of pages of the book.

Certain tendencies are very apparent from this analysis. The oldest text evidently approaches the subject of zoology from the physiological point of view. There ensues then what may be termed the natural history point of view, stressing external features and habits. Then comes a period represented by Orton and particularly by Colton in which the morpohology

	Comparative physiology	Embryology	Life History	Habits	Economic Zoology	Geographical distribution	External morphology	Internal morphology	Evolution
Daugherty's Principles of Economic Zoology, 1912	3.8	1.7	4.3	20.	10	5.	31.3	9.6	0.
Davidson's Practical Zoology, 1906.	2.6	2.	14.5	14.5	20.	0.	23.3	7.6	3.8
Kellogg's "The Animals and Man," 1911.	8.	0.1	7.9	14.	9.5	28.	3.3	3.2	4.9
Linville & Kelly, Textbook of Zoology, 1906.	7.8	3.	5.5	6.1	4.8	4.4	31.8	28.8	6.2
Kellogg's Elementary Zoology, 1901.	3.	1.5	8.6	11.3	4.	3.5	34.3	23.3	1.6
Davenport's Introduction to Zoology, 1901.	0.	5.5	3.4	28.	5.4	5.6	24.9	0.2	0.
Colton's Practical Zoology, 1886.	0.9	1.3	7.3	0.	0.	0.	32.3	41.6	0.
Orton's Comparative Zoology, 1876.	0.5	4.3	2.4	3.4	0.	3.	40.	27.4	0.
Tenney's Natural History 1866.	0.	3.2	4.7	34.1	7.1	5.1	43.6	0.	0.
Agassiz & Gould, Principles of Zoology, 1848.	28.4	8.8	4.3	2.8	0.	9.8	0.	0.	0.

of the animal seems to be the matter of supreme moment. Linville and Kelly, the text most widely used now, is to be classed with this group. Davenport's Introduction to Zoology seems to swing back toward the old natural history point of view, emphasizing external features, especially those that relate to habits, in other words it takes the ecological view point. While not the most recent therefore, it may be looked upon as marking, perhaps, the most advanced stand in modern zoology. In the very recent books there is an evident tendency to include a good deal of practical or economical material; this is especially true in Davidson, but not as true in the Daugherty's Economic Zoology, although its name would indicate that the effort of the book is to stress this particular phase.

It is very evident from this abstract of the complete table and much more evident from the complete table itself, that the texts in zoology are far from indicating any unanimity of opinion as to the proper content of a high school zoology course.

PROGRESS OF SECONDARY SCHOOL AGRICULTURE IN ILLINOIS

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Agricultural teaching in the secondary schools of Illinois has not spread so rapidly as it has in many other states, but the growth of this phase of vocational education in the state has been sane and progressive. Two years ago there were thirty-two high schools in the state giving instruction in agriculture; the number has probably been doubled by this time.

The length of term given to agriculture in most cases is one year, many schools are offering two years by alternating courses and giving only one course each year. Only three schools to my knowledge are offering four-year courses in agriculture. Four or five schools offer special short courses during the winter for boys and girls who cannot attend school regularly.

The year of agriculture is usually given in the first year of high school and made elective to students in other classes. Warren's Elements of Agriculture is the text generally used.

When agriculture is given in the first year the students of course have very little knowledge of science to which they can relate their agriculture; on the other hand, the agriculture may furnish a motive for further study and better appreciation and understanding of the sciences which follow later. The first year agriculture often takes the place of a general science, since it invades freely into the field of botany, zoology, chemistry, physics and other pure sciences.

It may be of interest to note that at the last meeting of the State High School Conference at the University last fall, the Agricultural section recommended that a year of general science be given before, or in connection with, the study of agriculture. It was the opinion of the Section that agriculture should be taught as a vocational subject and leave the related scientific subject-matter of the various sciences to their respective fields. For example, in agriculture we should teach in regard to alfalfa, less of its botanical relationships and facts and more of its economic value and how to grow it and use it.

As the schools are now manned and equipped, more of the science of agriculture can be taught than the art. The principles governing the application of the biological and physical sciences to the art of agriculture are as well taught, and have as much educational value as the so-called pure sciences, which have been taught for a much longer period of time. The graduates from our colleges of agriculture are usually well prepared in the sciences as well as in practical agriculture, and they are therefore better prepared to teach the sciences with agriculture, than are the science men to teach the agriculture with the sciences.

Those of us who believe in agricultural education must see to it, however, that the teaching be on a sound basis and that high standards of scholarship be maintained. I do not believe there is any more danger here than there is in the teaching of other sciences. If the pure sciences are made "too pure" for high school, the fault is just as grievous as it would be were the applied sciences made merely recipes for action. The applied sciences, it seems to me, have this additional value over the pure sciences for educational purposes—in that there is opportunity in the application of the science to useful ends, to understand and appreciate the pure science as well.

As to whether the teaching of agriculture in the state at this time is well organized in relation to existing courses in the curriculum, or whether it is on the right basis, I am not able to say with any degree of correctness. The whole matter is

in a changing condition, and no one seems to know what is right. Because the pure sciences had to be taught by laboratory equipment and experimental methods, may not be a reason why agriculture should be taught in this way within four walls, especially. Because one science should logically precede another, is no reason why agriculture should fit into a scheme of precedence. The danger is that our pure science men are trying to fit agriculture into a hide-bound system of text-books, laboratories and other academic methods. Agriculture is the application of nearly all sciences, and it is out-of-doors. These facts should govern our policies and methods in teaching the subject.

Larger and better things are coming for agricultural education in our state. It may not be long until legislature fiat will place agriculture into all the schools. Many men and women are at work trying to find the best way by which agriculture in the public schools will not only contribute to the educational growth of the boys and girls of the school, but be a constructive factor in the economic and permanent growth of the state.

At the meeting of the High School Conference referred to above, the Agricultural Section adopted courses of study in general science and agriculture, and made recommendations as to books, equipment, and methods. These proceedings are being published and may be obtained soon from the writer.

RESISTANCE AND REACTIONS OF FISHES TO TEMPERATURE

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The relation of fishes to temperature has been a subject for considerable experimental and observational study in the past. The experimental work has dealt largely with the resistance of fishes to extremes of temperature, while numerous observations have been made both upon the resistance and the reactions of fishes to various temperatures. In 1853 Dr. John Davy experimented upon the resistance of a number of species of fishes to high temperatures, and in 1882, as recorded in Day's (1886) review of his work, Davy reported a considerable number of experiments upon the extremes of high tem-

perature which eggs, fry, and adults of different species can stand without being killed. He found the egg to be more resistant to high temperatures than was the young fish and probably also than the adult. At 85° F. (29.4° C.) both the young and the old fishes were dead while the eggs still lived to hatch into normal, vigorous larvae. These results are not entirely satisfactory however, for one experiment is stated to have been performed upon the eggs, young, and adult of a given species under similar conditions. Day (1886) observed fish in the government garden in Madras, where, in December 1866, he found the maximum daily temperature of the water to be 72° F. (22.2° C.) He states that the Indian carp thrives in the lower rivers where the temperature at mid-day rises to 92° F. (33.3° C.) Carter (1887) gives a table of fishes which are sensitive or hardy in warm waters. He includes both marine and fresh water species giving the average maximum temperatures which species from the two habitats can stand. These maximum temperatures do not differ much for the two habitats being 50°-71° F. (14.4°-21.6° C.) for the fresh water species mentioned and 58°-71° F. (14.4°-21.6°C.) for those from salt water.

There are recorded cases where fishes are reported to have inhabited much higher temperatures, but most of these records are not well authenticated. Such cases will be found in the literature cited. There are also many records of fishes having endured low temperatures without injury. Many of these records are common knowledge and must be taken for what they are worth. There are, however, some definite experiments upon the relation of fishes to low temperature. Heath in 1883 tells of freezing several species of fishes in solid blocks of ice. He found that species thus frozen would regain their normal activities upon slow thawing. Other species were not so resistant, while all the species he tried died if kept in the frozen condition for more than a few hours. Pictet (1893) reports a number of experiments of the same sort. He kept gold fish at 0° C. for 24 hrs., and then slowly cooled the water to -8° to -15° C. The fishes were frozen solid and were as brittle as the ice. Upon thawing they became normal again and swam about the pan as before. When cooled to below -20° C. they could not be revived.

Much of the value of such data as the above is lost because of the failure of the workers to give specific names and accurate reports of temperatures and other experimental conditions. Thus there are numerous observations and speculations

upon the influence of temperature upon the movements of fishes. Baird (1886) states that temperature is important in influencing the migrations of fishes and Verrill, according to Bumpus (1898) says the sudden death of the enormous numbers of "tile fish" in the year 1879 was probably due to a sudden lowering of the temperature of the waters usually warmed by the gulf stream. In 1899 Libbey began a series of observations to ascertain the connection between changes in temperature and the migrations of fishes. This investigation was merely a continuation of former investigations in which he had determined pretty definitely that movements of ocean currents and other changes in ocean temperatures are of very great importance in these migrations, (Bumpus '98). It is a matter of common observation among fishermen that certain fishes, for instance suckers, when they ascend the small streams in the spring to spawn, often seem to congregate in the warmer streams when there are numerous small streams of different temperatures to choose from.

PRESENTATION OF DATA

In the experiments to be briefly reported here, I have used the fresh water fishes of the creeks in the vicinity of Chicago and have performed with them two types of experiments, namely, resistance experiments and reaction experiments.

1. *Resistance Experiments*: These experiments have been of two sub-types. (1) Resistance to slowly changing temperatures, and (2) Resistance to suddenly changing temperatures. In the first sub-type the fishes were placed in a granite pan in about a liter of water (the species used have been small except in the case of the bull-head, in which case individuals not more than 4 in. long were used), at normal optimum temperature and the water was then heated gradually. The rate of heating was varied considerably in different experiments (5 min. up to 1 hr.) In killing experiments the heating was continued up to the point where death occurred; in other experiments the fish was taken out before the death point was reached.

As the water was being heated, the fishes gave very similar reactions, specific differences being quantitative rather than qualitative. At the beginning, the fish in the experiment swam about exactly as did the one in the control. As the experimental temperature increased, however, the activity of the experimental fish increased likewise. This increased activity usually became noticeable by the time the temperature in the experi-

ment had been raised as little as 2° C. above that of the control. With the gradual rise in the temperature of the experimental pan, the activities of the experimental fish became more and more marked until in a number of instances the fish attempted to leap out of the pan at a temperature still 2°-3° C. below the maximum for the species. At this point the swimming movements were still in perfect correlation, but, as the temperature approached the maximum for the species, lack of correlation began to develop and at a temperature of 1° C. or less, below the maximum, a sudden paroxysm set in. The fish "scooted" blindly about the pan, sometimes shooting over the edge. This intense activity lasted for about 30 seconds or less, when the fish fell to its side, making no visible movements other than feeble twitchings of the gills and fins. If at this point it was immediately removed and placed in cooler water it often recovered; the possibility of recovery varied with the species and size of the fish, the more hardy species (bull-head) and the larger individuals of the other species (cyprinids) being most likely to live. The paroxysm induced by temperature resembled so much that produced in other experiments (Wells '13) by lack of oxygen and excess carbon dioxide, that analyses were made to determine the amount of these gases present during the experiments. These analyses always showed a normal amount of oxygen to be present while the amount of carbon dioxide was if anything a little less than that of the control, the diminution being due to the higher temperature of the experiment.

In the attempt to determine a definite maximum temperature for the different species used it was found that a number of factors must be considered. The species used all resisted higher temperatures when the heating was gradual, than they did when it was comparatively rapid, thus showing some acclimatization to the higher temperatures. Large fishes of a given species were usually considered more resistant than were small ones of the same species. The physiological condition of the species was found to be important; it has been found that practically all the species of fishes occurring in the rivers and creeks in the vicinity of Chicago are a great deal more resistant to many kinds of stimuli, temperature included, in March and April, just before the breeding season begins, than they are in the latter part of June and first part of July, immediately following the breeding season. In fact resistance is so low at this latter time of year, that most of the species of cyprinid minnows cannot be transported into the laboratory from creeks an hour's ride out, even though ice be taken along

to keep the water cool. So low is the resistance at this time that these species often die from the shock of being seined out of the water and transferred to the fish bucket. Thus, if one were to draw the seasonal resistance curve of such fishes, it would be a rather regular curve, the highest point occurring in March and April and the lowest point in the latter part of June and first part of July, with the difference in the level of these two points a considerable one. From the low point the rise in resistance is very slow and gradual up to the latter part of September when the curve begins to rise more rapidly up to the high point in the spring.

For the above reasons it has been found impossible to state that any certain temperature is the maximum which can be endured by a given species. There are, however, definite specific differences in the resistance of fishes to temperature as well as to other factors. Of the species used in the experiments, the black bull-head (*Ameiurus melas*) was the most hardy, even though none but young of this species was used. This species could be raised to 35°-36° C. before death occurred. The other species follow in the order of their increasing resistance. Silver shiner (*Notropis atherinoides*) 27°-28° C.; straw-colored minnow (*Notropis blennius*), 28°-29° C.; common shiner (*Notropis cornutus*), 28°-30° C. (Temperatures are approximate). Field and experimental observations have been made upon a large number of other species, but will not be tabulated here.

In experiments where fishes were subjected to sudden changes of temperature, the changes were made through a large number of the possible combinations existing in a range of temperature, the highest point of which is just below the general maximum for the species and the lowest point, one or two degrees above freezing. Thus one series of experiments consisted in changing adults of *Notropis blennius* from 28° C. to 3° C., from 25° C to 3° C. ,from 22° C. to 3° C., and so on down to a last change of from 10° C. to 3° C. In all the experiments the method employed was to arrange the pans of cold and warm water along side each other. The temperatures of these pans were kept constant for each test. The fish was quickly lifted from one pan to the other in the direction in which the change was to be made, i. e., from warm to cold or vice versa. The general effect of change from colder to warmer is, as has been noted, to increase the activity of the fish; the reverse change tends to diminish these activities. In general this increase or decrease of activity proceeds regularly

and proportionately with the change in temperature, but at the higher and lower limits of temperature used in these experiments, there is a breaking over the bounds of normal activity and a period of abnormal activity ensues. This period has been described in the case of high temperatures, where it comes on as the temperature nears the death point for the species, and it will occur whether the heating be slow or rapid, the only difference being that with slow heating, it occurs at a higher temperature than when the heating is rapid (.5°-1.5° C. difference for the different rates tried). In the experiments where the fishes were changed from warmer to colder water it was found that with certain changes a paroxysm of activity similar to that of heating follows the transfer. To produce this result the temperature change must be sudden and relatively great. With *Notropis blennius* adults, for instance, a sudden change into water which is at least 10° C. colder than that in which the fish has been kept will produce upon the part of the fish violent activities, providing the lower temperature is not above 5°-6° C. Thus a sudden change from 15° C. to 3° C. will give the reaction, while a change from 25° C. to 13° C. will merely result in a decrease of normal movements, as rate of gill contractions, etc. A gradual cooling of the surrounding water does not result in any marked reaction at any point down to freezing (Heath '83). A typical experiment will illustrate this reaction in which the paroxysm, due to change from warmer to colder temperature occurs. "An adult *Notropis blennius* was suddenly transferred from water whose temperature was 13° C. to water of 3° C. The fish had been kept in the 13° water for four days. When dropped into the cold water, it lost all motion and gill movements could scarcely be detected. It lay thus on its side for 1 minute and 30 seconds; began to swim a little, and then suddenly "scooted" madly about the pan. This blindly violent activity lasted for 5 seconds; fish again fell to side; lay motionless for 5 seconds; pectoral fins began to twitch; gill movements weak and irregular; gradually movements of gills and fins became more vigorous until at end of 22 minutes, fish was swimming about pan; still unable to maintain equilibrium; at end of 34 minutes floating easily and normally in the cold water." The bull-head does not show any such marked reaction, however great the temperature change, its adjustment remaining within the bounds of normality in all changes from warmer to colder water. Small cyprinid fishes were less affected by the change from warm to cold than were adults of the same species, the small fishes as a usual thing not passing through a par-

oxysm in adjusting to the lower temperature; in any case the time required to regain normality was always less in the case of the smaller (younger) fishes of a given species. It will be remembered that the reverse was the case with regard to resistance to high temperatures. In no case was death the result of sudden change from higher to lower temperatures, though the widest range possible between the specific maximum and freezing was tried. It may well be, however, that sudden lowering in temperature does result in death where certain species are concerned. In the planting of trout fry in cold mountain streams, the change from the warm water of shipping cans into the cold water of the stream has been blamed for the high percentage of death on the part of the fry in some cases. It is a common custom among fish culturists to cool the water in the cans gradually down to the temperature of the stream, by gradually adding the colder water to that in the cans. Sudden changes from lower to higher temperatures often result in marked temporary increase in activity, but there is no loss of correlation of movements unless the higher temperature is near the maximum for the species.

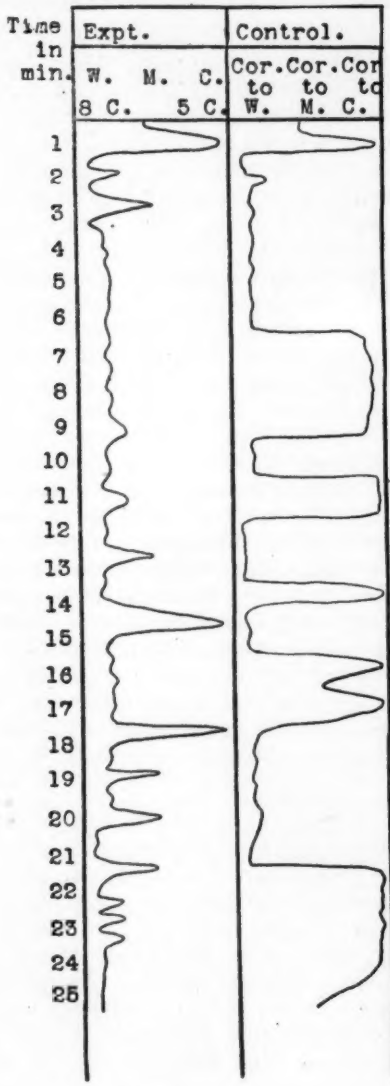
In another series of experiments it was found that the time which is required for a fish to become normal in cold water is proportional to the time which it has been in the water of higher temperature. This proportionality does not hold after the fish has been in the warm water for more than an hour or two, as the fish seems to become completely adjusted by that time and further stay does not alter its actions when returned to cold water. In one series of experiments of this sort, it was found that if an adult *Notropis blennius* is transferred from 3° C. to 15° C. water for 1 minute and then back into the 3° water, it is noticeably affected, but is normal within 1 minute. If left in the warm water 5 minutes, is normal in 5 minutes after being returned to the cold; 10 minutes in warm, normal in 7 minutes in cold; 20 minutes in warm, normal in 10 minutes; 40 minutes in warm, normal in 15 minutes in cold. Up to this point adults of this species always became normal in the cold water without passing through the paroxysm. When left in the warm water for 50-60 minutes, however, the paroxysm occurred 1 minute after transfer to the cold. Further stay in the warm water had no increased effect except to increase somewhat the total time elapsing before complete equilibrium in the cold water was established. A single fish could be made to pass through the paroxysm many times, the only permanent adjustment upon the part of the fish being a slight increase in its ability to resist the shock of the sudden change

from warm to cold. This was indicated by the fact that to produce successive recurrences of the paroxysm, the temperature change had to be made successively larger or the fish left for a successively longer time in the warmer water.

2. *Reaction of Fishes to Temperature*: Under this head are included a number of experiments which were performed by putting the fishes into a long narrow tank arranged so that the water flowing in at one end was of a different temperature from that flowing in at the other. The water of the two temperatures flowed to the middle of the tank and thence out through drains at top and bottom. The result was a mixing of the water, especially of the center third so that a temperature gradient was formed. This gradient was accurately determined by testing with thermometers graduated to tenths of a degree C. The fish was introduced at the center of the tank and a graph (Fig. 1) of its movements was made according to the method first used by Shelford and Allee ('13). A glance at the figure, which is that of a typical graph, will make the method and results clear. The graph is selected as typical of a large number of similar ones; it shows that the fish in the experiment reacted very definitely to the temperature gradient, selecting in this case the warmer end. Furthermore it will be noted that most of the turnings back from the colder portions of the gradient occurred some time before the fish had encountered the coldest water. Measurements showed that the fish detected and reacted to variations in temperature of no more than .1° C. All species tried were equally sensitive. Other experiments showed that fishes tend to select an optimum temperature (16°-19° C.) for they will turn back from warm water when it is above this temperature. No attempt was made to alter the optimum temperatures of the species used but it is probable that the optimum varies with the physiological state.

Discussion: The above experiments suggest that fishes possess a temperature regulating mechanism of the most delicate order. It has been shown that practically all cold blooded animals maintain body temperatures above that of the surrounding medium. Kidder (1879) showed that certain marine fishes maintain temperatures above that of the surrounding water (5°-20° C for different species). There must therefore be present in these forms, just as in warm blooded animals, a mechanism for temperature regulation. Furthermore, the convulsive activity at high temperatures and upon sudden

Figure 1, showing the reaction of a small (4 in.) micropterus dolomieu to a temperature gradient. The graph in the experiment shows a decisive selection of the warmer end. The control is neutral. Headings in control mean "Corresponding to Warm." etc.



changes to lower temperatures may be due to a failure of the mechanism to adjust to the extreme change. This explanation is supported by the fact that more adjustment was made in the case of slow heating than in the case where heating was rapid, and also by the fact that complete adjustment took place when cooling was slow. Thus acclimatization to temperature may be looked upon as resulting from an adjustment of the temperature regulating mechanism.

Experiments upon the rate of metabolism under different temperature conditions have not been carried out as yet. Just how the rate of reaction is affected, for instance, by raising the temperature of the water surrounding a fish is not certain. It is probably correct to state that in general the rate of metabolism is increased with increase in temperature, and diminished with decrease. But whether or not each degree's rise or fall in temperature increases the carbon dioxide output to the same extent is a question. Very probably the effect upon the metabolism, of changes in temperature is not the same at different points in the temperature scale, that is to say, the metabolism of a fish at 3° C. may differ from its metabolism at 25°C., not only quantitatively but qualitatively as well. Furthermore the factors that cause the fish to pass into a state of uncontrolled convulsive activity at the stages of heat and cold rigor and what heat and cold rigor are in themselves, are questions that can be answered only by means of quantitative experiments which are yet to be undertaken. At this time it seems plausible to look upon these reactions as outward manifestations of qualitative or cumulative quantitative changes in the metabolism of the organism.

TEMPERATURE AND THE DISTRIBUTION OF FISHES

It is interesting to find that forms where the activities of the individuals are so dependent upon the conditions of the surrounding environment, possess exceedingly delicate mechanisms for the detection of environmental changes. Thus it has been shown that they are able to recognize very minute differences in acidity, (Shelford and Allee, '13), (Shelford, '14) and in the foregoing pages we have seen that they are also exceedingly sensitive to slight changes in temperature, their sensitiveness in this respect far exceeding that of warm blooded animals. This fact becomes a suggestive one when thought of in connection with the life activities of fishes and the resulting distribution of these forms through their reactions. (The relation of resistance to reaction has been discussed in a former

paper (Wells, '13) and will not be taken up here. If fishes can detect and will react to so small a variation in the temperature of the surrounding water as 1° C., it must be that they are continually reacting to this factor in all fish environments for such small differences in temperature must exist even in the smallest body of water. It has been suggested that temperature has much to do with the migrations of salt water fishes into fresh water streams, and the reaction experiments here outlined furnish support for such an idea. We must not attempt to limit the accuracy of such migrations to the temperature factor, however, for there are many other factors to be considered. Undoubtedly density, salinity, gaseous content, and acidity, as well as temperature, play their part in this phenomenon. The final solution of the problem must take all factors into consideration.

Summary: 1. The resistance of fishes to temperature varies with the species and with the size of the fish. Large fish of a given species are more resistant to high temperatures than small fish of the same species, but the small fish adjust to sudden changes from warm to cold more successfully.

2. There is no definite maximum temperature for a given species of fishes; the maximum varies with the rate of heating, with the size of the fish and with its physiological condition.

3. Fishes detect and react to exceedingly small (.1° C.) variations, in the temperature of the surrounding water.

4. Both the resistance and the reaction experiments indicate that the fishes experimented upon, possess a temperature regulating mechanism which is much more delicate than that of the warmer animals, though not as efficient in maintaining a constant body temperature.

5. The effect of temperature upon the migrations and distribution of fishes is obvious, since variations in temperature, far in excess of the minimum variation to which fish will react, are known to occur constantly in fish environments.

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EVAPORATION AND SOIL MOISTURE IN FORESTS AND CULTIVATED FIELDS

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I. *Evaporation.* Considerable work has recently been done in the Chicago region by Fuller[1] and others on the evaporating power of the air in such natural plant associations as the Cottonwood, Pine and Oak dunes, Edaphic prairie and Beech-Maple forest. In this work the beech-maple forest has been considered the most satisfactory standard for comparison of other plant associations and it has therefore been used in this paper as a basis for comparing the evaporating power of the air in cultivated fields. The region near Otis, Indiana, offers excellent conditions for such a study and is accessible to Chicago, therefore it has been selected for this work. The beech-maple forest for this investigation is bordered by cultivated fields of wheat and oats which have soils of a similar nature. The methods of cultivation in the wheat field are evidently superior to those in the oat field, as indicated by the greater depth of humus and the texture of the soil. The evaporating power of the air and the soil moisture of these habitats has been determined during the season extending from May 3 to August 23, 1913.

In determining the evaporation power of the air the Livingston[2] porous cup atmometer was used according to the usual methods employed. All instruments were properly standardized before being set up and at frequent intervals during the season. By comparison of these coefficients with that of a standard atmometer, all readings were reduced to a common

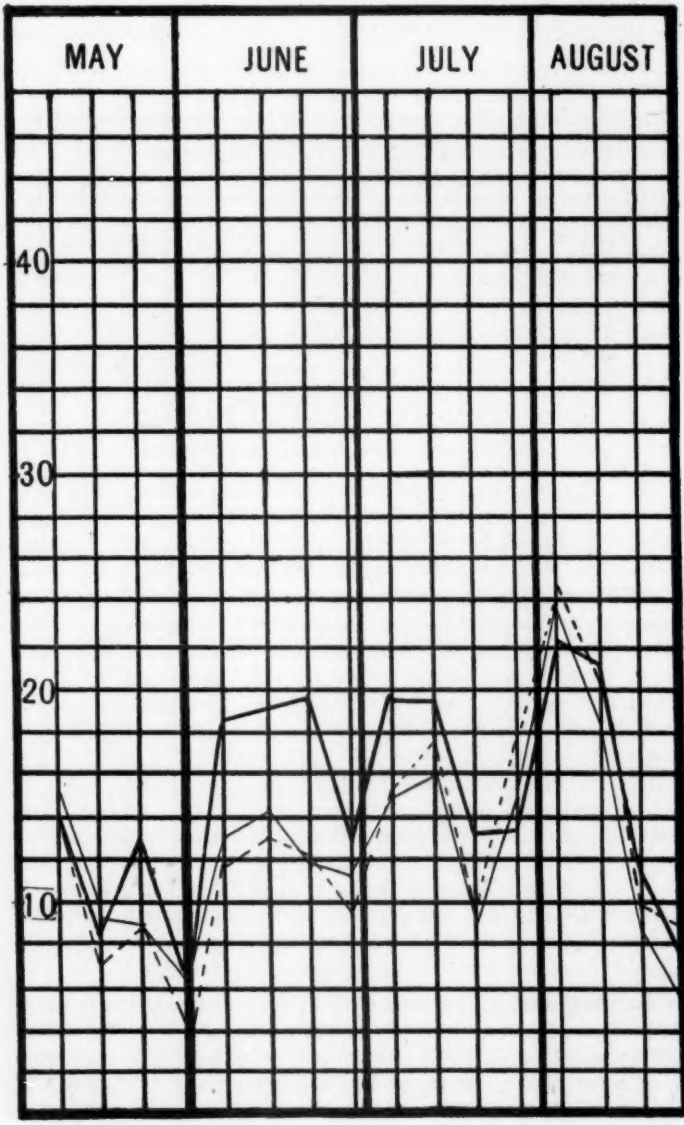

Figure 1: Graphs representing the range of evaporation at three stations in the beech-maple forest.

basis. Throughout the season readings were taken once each week and the results reduced to the average daily loss for each week. The accompanying graphs have been made with the average daily loss in cubic centimeters as ordinates and with weekly intervals as abscissae.

In the beech-maple forest three stations were established in representative positions. During this season the herbaceous vegetation was somewhat sparse and therefore probably modified conditions from time to time but little. One of these stations was placed on the crest of a low ridge which gave it somewhat more exposure to the wind. In figure 1, this station, represented by the heavy line, has a rather higher evaporation rate altho it is fairly parallel with the other two stations. Three stations were established in the wheat field, which had also been sown with clover, with more or less uniform exposure. One of these stations was surrounded by taller wheat and more vigorous clover, which produced a luxuriant crop after the wheat had been harvested. In figure 2, this station, represented by the heavy line, has a slightly lower evaporation rate. Three stations of uniform exposure were established in the oat field about June 8th, which gave fairly parallel curves. The average of these curves is plotted in figure 3 (c). No records were taken after the oats were harvested early in August.

II. *Soil Moisture*: Through the work of Briggs and Schantz[3] and others the *wilting coefficient* has been established as a more or less satisfactory standard for the comparison of available growth water for plants in various soils. It represents the water content above which the growth takes place, and is expressed in percentage of dry weight of the soil.

In the determination of the soil moisture in the habitats studied, weekly samples of soil were taken from representative stations at depths of 7.5 cm. and at 25 cm. below the surface. This soil was brought to the laboratory in closed jars where it was weighed and dried at a temperature of about 104 degrees C., until it reached a constant weight and a percentage of water was calculated on the basis of this dry weight. The wilting coefficient of the same soils were obtained by the wax seal method of Briggs and Schantz,[3] and also by the indirect centrifuge method of the same workers. In figures 4 and 5 graphs have been plotted representing the range of soil moisture on the ordinates and the weekly readings on the abscissae. Upon these same diagrams the wilting coefficients have been represented in dotted lines. The available growth water is therefore represented by the intervals between soil moisture and wilting coefficient.

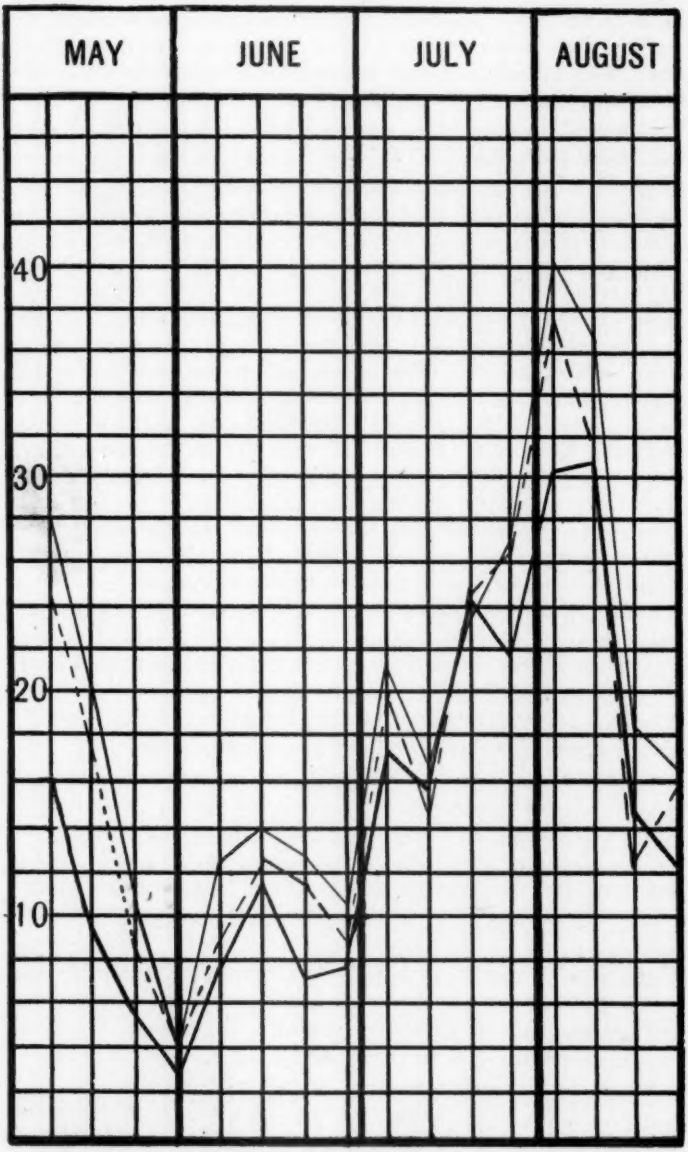

Figure 2: Graphs representing the range of evaporation at three similar stations in a wheat field.

While there is a general agreement between the individual and average curve representing soil moisture, several points of variation may be accounted for by corresponding changes in conditions. In figure 4 the variations noted about July 1st may be ascribed to weather conditions, while in figure 5, the ripening and harvesting of the wheat may affect the changes noted at this time since the corresponding evaporation was not high.

Weather conditions may account for the decrease in soil moistures about August 1st, since there is a corresponding increase in evaporation.

In figure 5 the wilting coefficient of two strata coincide. This is probably due to deep cultivation rendering the soil more or less homogeneous.

As pointed out by Fuller[1], the most significant comparisons are those shown in table 1, under growth water. The mean growth-water of the beech-maple forest is taken as the standard and represented by 100. This furnishes a quantitative statement of the relation of different habitats in their mesophytic conditions. Another comparison of habitats may be shown by the ratio between the mean weekly growth water and the evaporation rate for the same time. While it may be claimed that these units are not comparable, the ratio seems to give a quantitative relation between the habitats which is thought to be valuable. Since the growth water represents the available supply for plant growth and the evaporating power of the air represents the demand made by the plants on the available water, it seems advisable that such a comparison be used in this kind of work.

SUMMARY

The evaporation rate at the surface of cultivated fields is somewhat parallel to that of the climax beech-maple forest and shows corresponding variations due to changes in weather conditions. After crops are harvested the evaporation rate is greatly increased, due to the increased exposure.

In the beech-maple forest the soil moisture is much higher in the stratum due largely to the great amount of humus. In this association the wilting coefficient was reached only once during the season.

In the wheat field the upper stratum shows a marked response in soil moisture due to periodic rainfall. In this association the soil moisture falls decidedly below the wilting coefficient after the wheat is harvested.

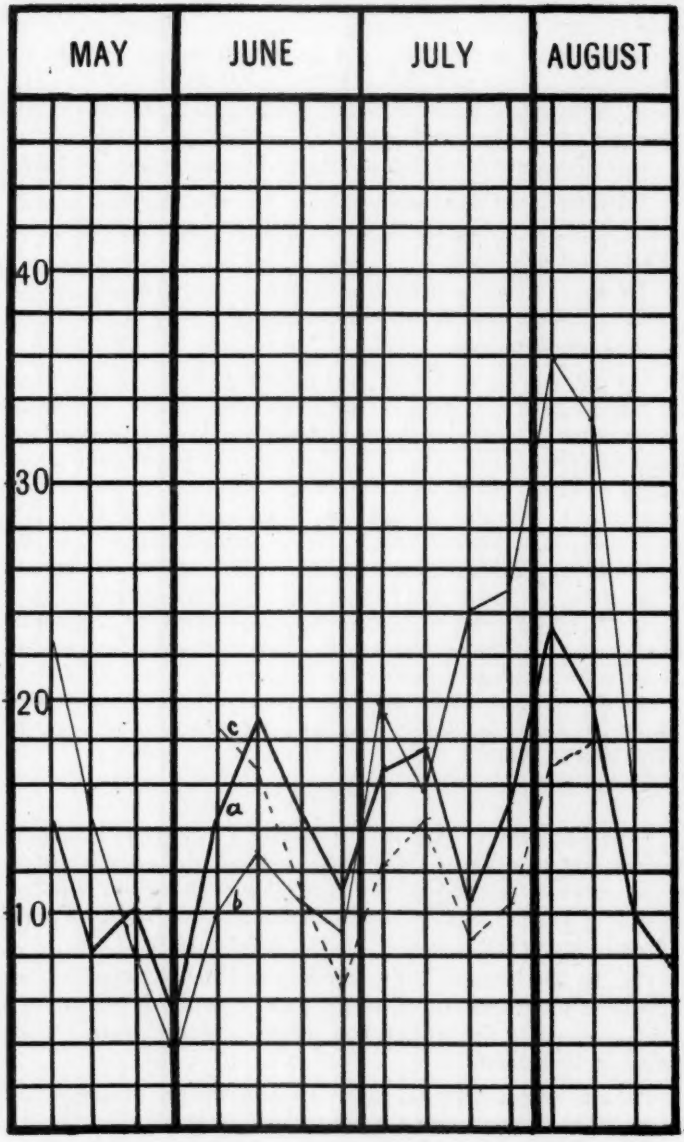

Figure 3: Graphs representing the average evaporation of three stations each in (a) beech-maple forest, (b) wheat field, and (c) oat field. ("1" represents the time of harvesting wheat).

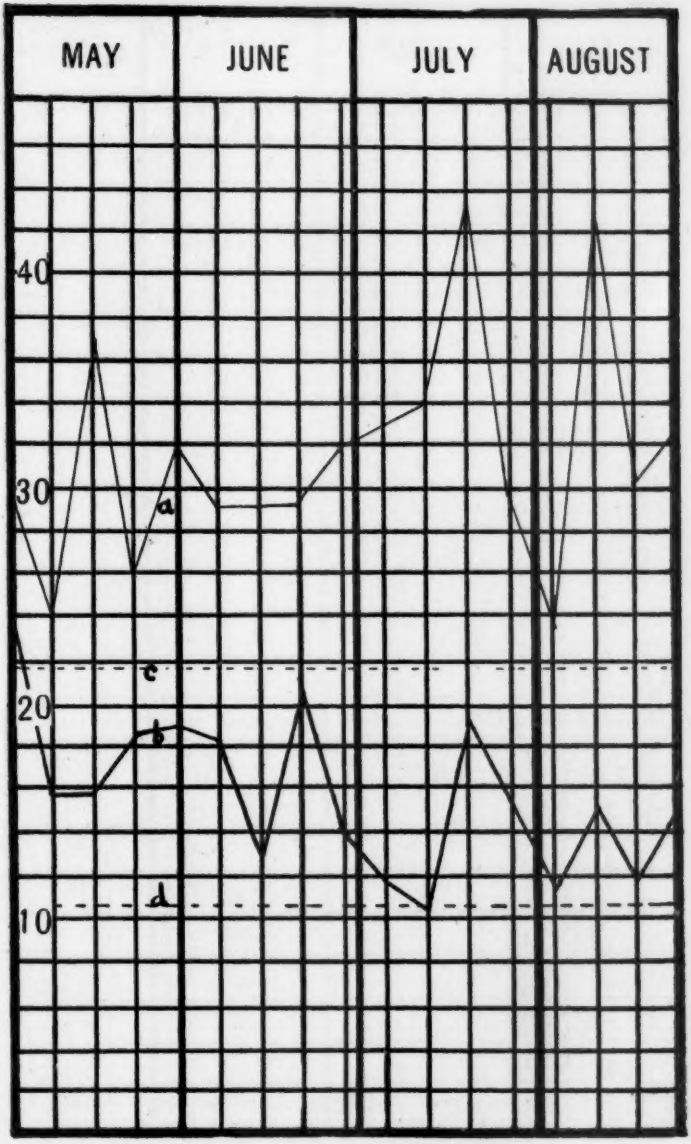

Figure 4: Graphs representing soil moisture in beech-maple forest at (a) 7.5 cm., (b) 25 cm. below surface. Also wilting coefficient of soil moisture at (c) 7.5 cm. and (d) 25 cm.

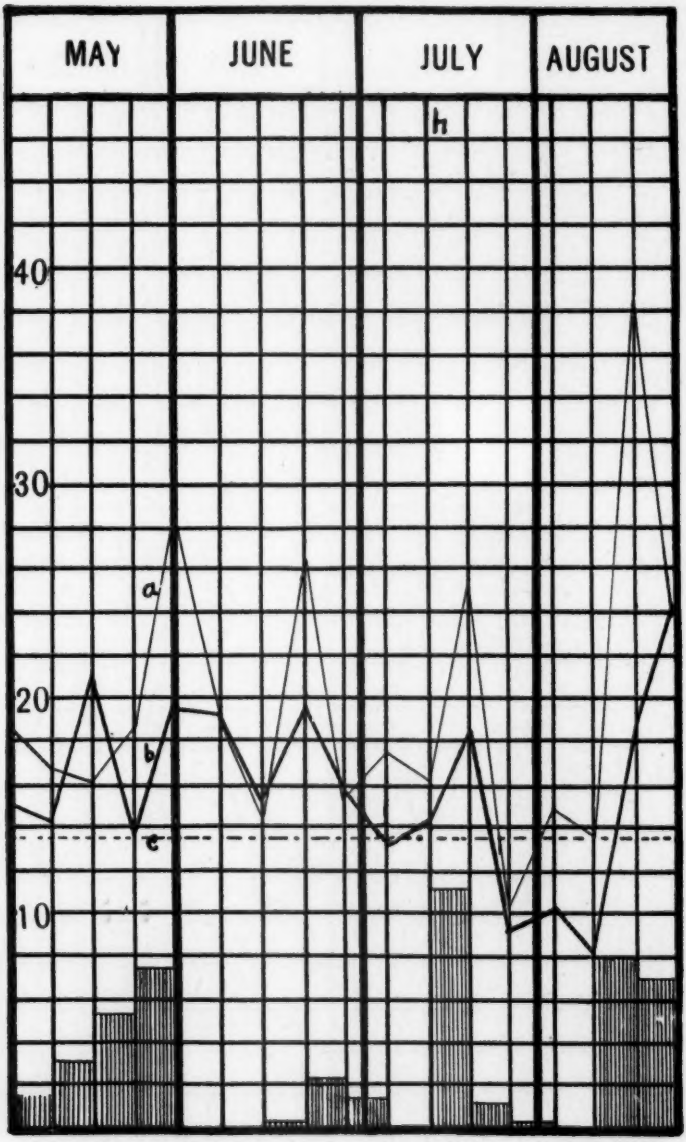

Figure 5: Graphs representing soil moisture in wheat field at (a) 7.5 cm., (b) 25 cm. below the surface. Also the wilting coefficient of soil at (c) 7.5 cm. and 25 cm. Weekly rainfall at bottom graph.

The upper stratum of the oat field also shows considerable variations which correspond more or less to those in the wheat field.

In order to determine the relation of climatic conditions to crop production the work on soil moisture and evaporation should be extended to deeper strata of soil and to higher strata of the atmosphere. Soil and air temperatures should also be recorded in these extended strata since such temperatures probably are directly effective on plant growth. The amount of precipitation and of irrigation water should also be recorded throughout the year, together with the soil conditions which effect the conservation of the same. The distribution and stages of development of the stem and root systems should be determined from time to time as the crops progress. The osmotic force of the roots of various crops in comparable stages of development may also be of interest in this connection.

The above methods of determination can be profitably applied to any crop at different stages in its development and under different methods of cultivation in order to obtain a quantitative statement of the relative effectiveness of methods of cultivation.

I wish to acknowledge many helpful suggestions by Doctor George D. Fuller, under whose direction this work has been done.

TABLE I.

Wilting Coefficients and Mean Percentage of Growth-Water in Various Associations from June 1 to August 16, 1913

Name of Association	Depth in cm.	Wilting Coef.	Growth-water			Ratio of Evap. & growth-water
			Per cent	Mean %	Comp. Amts.	
Wheat field.....	7.5	13.6	6.3	3.65	55.	5.25
1913	25.0	13.7	1.4			
Oat field	7.5	14.1	9.6	6.00	90.	2.17
1913	25.0	10.5	2.4			
Beech-Maple	7.5	21.8	10.4	7.35	100	2.02
1913	25.0	10.6	4.3			
*Beech-Maple	7.5	13.5	5.5	4.25	100.	2.00
1911	25.0	9.5	3.3			
*Beech-Maple	7.5	13.5	5.0	4.5	100.	1.18
1912	25.0	9.5	4.0			

*Taken from Fuller's data in the same region.

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SOIL MOISTURE AND PLANT SUCCESSION

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The direct source of the water supply of plants being the moisture in the soil, the amount of this moisture is evidently of the highest importance to vegetation. This has been recognized by many leading ecologists and phytogeographers, but very little data have been made available as to effects of definite quantitive amounts of this moisture upon the vegetation or of the amount and range of the soil moisture in different plant associations. This has been largely due to the difficulty in relating the amount of soil moisture to the production of vegetation. It is clear that there can be no direct relation between the percentage of water present in soils and the amount available for plant growth, for a sandy soil with 15 per cent of moisture is at or near saturation, while a stiff clay with 15 per cent of water is so dry that all plants wilt in it, even with a humid atmosphere.

Efforts have been made to establish a standard by which the actual water content of soils could be related to plant production. *Clements*[1] determined the amount of water remaining in soils when pronounced wilting occurred, and regarding this as non-available, termed it the *echard,* while the difference between the amount actually present in the soil and the echard was the available water, or *chresard. Livingston*[2] recognized that the *water-holding capacity* of soils varied and had a fairly constant relation to the soil moisture conditions. Then *Briggs* and *McLane*[3] determined the *moisture equivalent* of soils by the application of a centrifugal force of 1000 times that of gravity thus providing a method of measuring and comparing the retentiveness of different soils for moisture acted upon by a definite force. This had the advantage of being measured in absolute terms, and of being reproducible within narrow limits of error. It remained for *Briggs* and *Shantz*[4] to refine the methods of determining the percentage of water in soils when permanent wilting occurs in such a plant as the standard Kubanka wheat, giving the *wilting coefficient,* and further to show that a constant relation existed between the moisture equivalent and the wilting coefficient; that is,

$$\frac{\textit{moisture equivalent}}{1.84} = \text{wilting coefficient}$$

They also clearly demonstrated the fact that plants continue to take water from the soil long after the wilting coefficient is reached. The writer, believing that none of the water absorbed

from soil whose moisture content is below the wilting coefficient is used for the growth of the organism, has used *growth water*[5] for the soil moisture in excess of the wilting coefficient.

METHODS

The soil moisture determinations here reported were made in the plant associations described in this paper during the years 1911-12, from the first of May to the end of October. In making the determinations, weekly samples, each consisting of 200 to 250 grams of soil, were taken in each of the associations at depths of 7.5 cm. and 25 cm. In order to provide against unnecessary error, each sample consisted of two portions of some 100 grams each, taken from spots several meters apart, care also being taken that no soil was taken nearer than a meter to holes where previous samples had been dug. The soil was placed in wide mouthed jars, tightly sealed, brought to the laboratory, weighed and dried at a temperature of 100° to 104° C. until it reached a constant weight (about 5 days). The percentage of water to the dry weight of the soil was then calculated.

The wilting coefficients of the same soils were determined by both the direct and indirect methods of *Briggs* and *Schantz*[4].

THE ASSOCIATIONS STUDIED

The series of associations studied consists of a succession beginning with a pioneer association dominated by the cottonwood, *Populus deltoides,* developed upon the sand dunes at Millers, Ind., and extending through succeeding associations, at the same place, dominated by *Pinus Banksiana* and *Quercus velutina,* known respectively as the pine and oak dunes. In the usual order of succession in the Chicago area the black oak forest is succeeded by one composed of the more mesophytic white oak, *Q. alba;* the red oak, *Q. rubra,* and the hickory, *Carya ovata,* and usually designated the oak-hickory forest. The example of this association studied is situated at Palos Park, Ill., and the results from this station have already been reported[6]. The climax of the succession is found in the mesophytic beech-maple forest which is found well developed at Otis, Ind. A description of the vegetation of these associations has been given by *Cowles*[1] and also by the writer in his more detailed report of these studies.[6]

An examination of the accompanying table (Table I) will show the growth-water for the ten weeks of midsummer for

1911-1912. The results for the cottonwood dune as already published for 1911[5] show two rather surprising things, namely, a remarkably small wilting coefficient, only 0.8 per cent at both depths, and a surprisingly constant supply of growth-water. Considered in relation to the wilting coefficient, the soil moisture actually present in the sand is continuously at least twice the amount of water necessary for the growth of such a plant as wheat. This is in striking contrast with the desert-like aspect of the association due to the almost complete absence of herbaceous undergrowth. Doubtless this constancy is largely due to the dry mulch maintained by the action of the wind and to the small quantities of water withdrawn by the sparse vegetation. The record for 1912 differs in no important particular from that of the previous year.

In the next association, the pine dune, the accumulation of humus increases the wilting coefficient to 1.1 per cent at 7.5 cm. and 1.0 per cent at 25 cm. The amount of growth-water is less than in the previous association and at three separate weeks during both of the years it quite disappears. Reasons for this failure are to be found in the comparative absence of the conserving dust mulch and in the much larger demands made by the denser stand of vegetation.

In the oak dune a slight decrease of humus seems to be indicated by the slightly lower wilting coefficient, but on the whole there is a somewhat greater supply of growth-water.

The water supply for the oak-hickory forest has already been reported in detail[6] and it is only necessary here to point out that the growth-water more than doubles that in any previous association.

The climax beech-maple forest shows the accumulation of humus in its wilting coefficient of 9.5 per cent at 25 cm., being increased to 13.5 per cent at 7.5 cm. The large and unfailing supply of growth-water is indicative of truly mesophytic conditions. As in the other associations, the upper stratum shows the larger amount of variation. Comparing the two seasons, it will be seen that while the averages are about the same, the year 1912 shows a much greater uniformity in the range of moisture supply.

GENERAL CONCLUSIONS

An examination of Table I as well as a general knowledge of conditions of growth in these associations indicates that only during midsummer is there any scarcity in the supply of

the habitats. It has therefore seemed desirable to limit our comparisons to this period of stress, and to establish the rather arbitrary limit of the 10 weeks from the last of June to the first of September. A summary of these weeks appears in Table I.

TABLE, I.

Wilting coefficients and mean percentages of growth-water in the various associations during the 10 midsummer weeks of 1911-12:

Association	Depth in cms	Wilting coefficient	Growth-water				Ratio between evaporation and growth-water
			1911	1912	Mean	Comp. Amts.	
Cottonwood dune	7.5	.80	2.2	1.8			
Cottonwood dune	25.	.80	2.6	2.0	2.15	49	11.7
Pine dune	7.5	1.10	.9	.7			
Pine dune	25.	1.00	1.7	1.3	1.15	26	10.7
Oak dune	7.5	1.10	1.4	1.4			
Oak dune	25.	.90	.8	1.5	1.27	29	9.37
Oak-Hickory	7.5	9.0	3.2				
Oak-Hickory	25.	9.5	3.3		3.3	75	2.78
Beech-Maple	7.5	13.5	5.5	5.0			
Beech-Maple	25.	9.5	3.0	4.0	4.4	100	1.81

No one can realize more fully than does the writer the limitations of the data or the desirability of having them supplemented by more numerous determinations, especially from deeper strata. These limitations will make the conclusions more or less provisional and subject to modification and correction in the future. The most interesting and profitable comparisons are doubtless those to be made from a consideration of the growth-water data shown in Table I., and especially as expressed in the sixth and seventh columns, which contain the mean percentages of growth-water and the comparative amounts, the beech-maple forest being taken as a standard and its mean growth-water represented by 100. In the five associations that form the succession, the mean growth-water for midsummer of the two seasons will be found, if we except the cottonwood dune, to form a progressive series, the most mesophytic association having the largest amount. This was exactly what was supposed to be the situation, but hitherto no quantitive data of such moisture relationships have been available, it has been impossible to tell how much an association differs in its water conditions from the preceding or succeeding association. As has already been stated, the cottonwood dune, with a larger and more constant water supply than the two succeeding associations, must owe its surplus to the conserving power of its dust mulch and to the small outgo due to the paucity of its vegetation.

The comparative amounts of growth-water indicate even more clearly the relationship existing between the available water supplies of the associations, and should serve to emphasize the fact that the progressive increases in the water retaining power of the soil, due largely to its increased humus content, must play no inconsiderable role in causing the succession here, culminating in the mesophytic beech-maple forest. More investigation must be made before more definite comparisons can be made.

Another and still more important comparison may be instituted among the associations under investigation by considering the ratio between the average mean weekly evaporation rates for the 10 mid-summer weeks of the years 1910-1912, and the mean growth-water for the same period. These ratios are expressed in the final column of Table I. In determining these ratios it is recognized that the units of measurement in the case of the evaporation and the soil moisture are not directly comparable. Still it is thought that the comparison is a legitimate one, and institutes a quantitative comparison of the mesophytism of the habitats which is valuable and exceeds in accuracy anything hitherto attained. It is true that these habitats are limited to the lower stratum of the aerial and the upper strata of the subterranean vegetation, but as previously pointed out, these are the portions of the habitat that are of critical importance in the establishment and maintenance of associations, because in these the seedlings, both woody and herbaceous, develop. An extension of the habitat by the addition of the higher strata of the air and the strata of the soil containing all the aerial and subterranean portions of the vegetation would doubtless modify and decrease the steepness of the gradient between the various ratios.

The ratios may either be compared directly, remembering that the mesophytism of the various habitats varies in inverse ratios with the numbers expressing these ratios, or the beech-maple forest may again be taken as the standard and represented by 100, when the direct ratio of the mesophytism of the corresponding portions of the oak-hickory forest, the oak dune, the pine dune, and the cottonwood dune will be respectively 65, 20, 17, and 15. These comparative values of the moisture factors show such a surprising rate of increase as one proceeds from the pioneer to the climax associations, that it cannot be doubted that such a change in water conditions must be one of the chief, if not the most important cause of the succession of associations from the more xerophytic to the mesophytic.

SUMMARY

1. These data represent the range of soil moisture in the upper subterranean strata of the vegetation of the various associations.

2. The rate of evaporation in the cottonwood dune association both by its great amount and by its excessive variation, seems a quite sufficient cause for the xerophytic character of the vegetation and for the absence of undergrowth, in spite of the constant presence of growth-water.

3. The pine and oak dune association resemble one another closely in their supply of growth-water. The former is slightly more xerophytic during the midsummer weeks.

4. The amount of growth-water in the various associations varies directly with the order of their occurrence in the succession, the pioneer being the most xerophytic.

5. The ratios between the evaporation and growth-water in the beech-maple forest, oak-hickory forest, oak dune, pine dune, and cottonwood dune associations have been shown to have comparative values of 100, 65, 20, 17, and 15 respectively, and the differences thus indicated are sufficient to be efficient factors in causing succession.

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FURTHER NOTES ON THE POST-GLACIAL BIOTA OF GLACIAL LAKE, CHICAGO

BY FRANK C. BAKER

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At the Chicago meeting of the Illinois Academy of Science in 1911[1], the writer presented certain facts concerning the biota contained in the sedimentary strata of the bed of Glacial Lake Chicago. Since that time data have been accumulating which have added largely to our knowledge of the life of these early days. Attention has also been directed to the southwestern portion of Michigan, bordering Lake Michigan, which contains sedimentary deposits referable to several of the lake stages.

To understand the northward migration of the life, one must have clearly in mind the condition of this part of the country as the great ice sheet melted back into the Michigan basin. There was at first a large glacial lake in the Kankakee marsh area, known as Lake Kankakee, which extended northeasterly almost to South Bend; later came Lake Dowagiac which extended northeasterly up the area now occupied by the great Dowagiac swamp; still later, after this drainage was largely abandoned, a long arm of glacial Lake Chicago extended into Michigan and connected with the Grand River outlet of glacial Lake Saginaw.

Just how rapidly the biota followed the retreating ice is not known, but we may safely infer that certain hardy types (as for example the Physas, some Lymnæas, Sphaeria, Planorbis, etc.), took advantage of the new water courses at a very early time. It is this cold temperate, almost subarctic fauna that is found in the earliest deposits of glacial Lake Chicago.

Many, if not all, of the lakes in southwestern Michigan, (including Berrien, Cass and Van Buren counties), contain marl beds of post-glacial origin. The life entombed in these marl deposits, consisting of mollusks, reached these lakes, for the most part by direct migration from the region south of the Wisconsin ice sheet. In what manner and by what routes they came is one of the most interesting questions open to the student of zoogeography. Three localities in the region under discussion contain the remains of a more ancient life, one previously known, the others here recorded for the first time.

1. Trans. Ill. Acad. Sci., IV. pp. 108-116, 1912.

1. Buchanan, Berrien County

Two miles west and a little north of Buchanan, Berrien county, is a stretch of low land known as Bakertown marsh. The marsh was previously a lake about three miles long and a mile wide, but is now grown up in marsh grass and is practically dry. A ditch about a mile in length drains the marsh, and exposes the strata, which exhibit the following section:

VIII.	Marsh bog	16 inches
VII.	Recent peat	20 inches
VI.	Peat and drift wood	10 inches
V.	Lake silt (no shells)	8 inches
V.	Semi-ligneous peat	12 inches
III.	Shells and lake drift	8 inches
II.	Blue Clay	7 inches
I.	Quicksand	7 to 10 feet

The thickness of the sedimentary deposits above the sand is 81 inches, or 6 feet, 9 inches.

The quicksand (stratum I) evidently represents the period of Lake Dowagiac when the glacial waters rushed down the lake into the Kankakee River, loaded with sediment. The clay, (stratum II), represents a quieter stage, after the main drainage had shifted to the Chicago outlet. Stratum III probably represents the bottom of a larger St. Joseph River, for the species of naiads represented are mostly of the river type. An arm of Lake Chicago extended up the St. Joseph River from Benton Harbor to about the vicinity of Berrien Springs[2] and the river drained into this extension of Lake Chicago.

The fluviatile mollusks may have reached this locality from two sources; (1), by way of the Chicago outlet, across Lake Chicago and up the St. Joseph River; or (2), by way of the Kankakee when it was connected with the St. Joseph and Dowagiac rivers via South Bend. The mussels are mostly of the river type and their natural migration route would be by way of a river. Just how long after the formation of Lake Chicago the St. Joseph-Kankakee drainage persisted is not definitely known, but it is believed to have continued for some time in a more or less modified form. The naiades represent a climate fully as warm as the present and they could not invade the waterways of the icy drainage. Certain boreal types of mollusks could and evidently did take advantage of this waterway at an early stage. It is probable that both drainages were used and the fauna represents a mixture of the two migrations. This stratum may be safely correlated with the Tolleston stage of Lake Chicago.

2. See Leverett, Illinois Glacial Lobe, plate XV.

The five and a half feet of silt and peat above the shell deposit represent the later stages of this locality and indicate its change from a river to a lake and finally to its present marsh-bog character. The mollusks (42 species) and other remains of life found in this deposit are listed below.[3]

MOLLUSCA

Symphynota compressa (Lea)=*pressus* Lea
Symphynota costata (Raf)=*rugosa* Barnes
Anodonta grandis footiana Lea
Anodontoides subcylindraceus (Lea)
Alasmidonta calceola (Lea)=*deltoidea* Lea
Eurynia iris (Lea)=*novi-eboraci* Lea
Eurynia ellipsiformis (Lea)=*spatulatus* Lea
Lampsilis ventricosa (Barnes)
Sphaerium simile (Say)
Sphaerium striatinum (Lam)
Pisidium near *abditum* Prime
Pisidium compressum Prime
Pisidium medianum Sterki
Pisidium milium Sterki
Pisidium pauperculum Sterki
Pisidium roperi Sterki
Pisidium ventricosum Prime
Pisidium near *vesiculare*
Campeloma integrum (Say)
Campeloma integrum obesum (Lewis)
Campelima subsolidum (Anth)
Pleurocera elevatum (Say)
Goniobasis livescens (Menke)
Valvata tricarinata Say
Amnicola limosa (Say)
Amnicola lustrica Pilsbry
Physa ancillaria Say
Physa integra Hald
Physa heterostropha Say
Ancylus rivularis Say
Planorbis antrosus Conrad
Planorbis campanulatus Say (=*bicarinatus* Say)
Planorbis trivolvis Say
Planorbis deflectus Say
Planorbis parvus Say
Galba obrussa (Say)=*disidiosa* authors
Galba humilis modicella (Say)
Lymnaea stagnalis appressa Say
Carcychium exiguum (Say)
Succinea ovalis Say
Strobilops labyrinthica (Say)
Vitrea hammonis (Ström)=*radiatula* Ald

ARTHROPODA

Head of dipterous insect.

VERTEBRATA

Mammut americanus (Kerr)

Considerable driftwood was observed, but none was identified. The shells occurred in little colonies, just as they are found today. It is probable that these colonies represent localities where the water had brought together and deposited

3. Walker Nautilus, XI., p. 121; XIII., p. 34; 55.

a quantity of dead shells, drift wood, and other debris, and not colonies of living shells. The mastodon skulls were found in and under the stratum of semi-ligneous peat, showing that these animals waded into the river after the shells were deposited. They were probably caught in the boggy bottom and were drowned.

The multitude of lakes which dot the surface of Berrien, Cass and Van Buren counties, especially in the swampy area near the Dowagiac and St. Joseph rivers, nearly all have marl deposits correlative with the later stages of the Great Lakes history. Many of these date from the glacial Lake Dowagiac, which had its outlet through the Kankakee River, while others are relics of the early stage of Lake Chicago when an arm extended into Michigan and up the valleys of the PawPaw and Black rivers.

2. Magician Lake, Cass County

In the northwestern part of Cass county, and also partly in Van Buren county, is a lake of considerable size, known as Magician Lake. This body of water empties into the Dowagiac River through Dowagiac Creek. Swampy tracts and old shore lines indicate this lake was once considerably larger and deeper. On the north shore, and about midway of the lake, near the summer resort known as Magician Beach, is an old embayment which is a swampy terrace about two feet above the water line. The upper three feet are peaty and boggy; beneath this stratum is a marl bed of unknown depth, which is filled with mollusks, of which the following species have been identified:

Unio, fragments
Sphaerium simile (Say)
Pisidium compressum Prime
Pisidium variabile Prime
Pisidium noveboracense Sterki
Pisidium splendidulum Sterki
Pisidium adamsi affine Sterki
Valvata tricarinata Say; Central carina almost absent in some specimens.
Ammicola limosa (Say)
Ammicola lustrica Pilsbry
Paludestrina nickliniana (Sea)
Physa integra Hald
Physa ancillaria Say
Physa walkeri Crandall
Physa gyrina Say
Planorbis antrosus Conrad
Planorbis antrosus angistomus Hald
Planorbis parvus Say
Planorbis deflectus Say
Planorbis hirsutus Gould
Planorbis exacuous Say

Galba palustris (Müller).
Galba galbana (Say)
Galba obrussa decampi (Streng)
Galba obrussa exigua (Lea)
Lymnaea stagnalis apressa Say

Of the above 25 species and varieties, 5 species formed about 90 per cent of the bulk of the material. These species are indicated in the order of their abundance.

Valvata tricarinata
Planorbis parvus
Amnicola lustrica
Paludestrina nickliniana
Galba obrussa decampi

Lymnaea stagnalis appressa, Galba galbana, and *Physa walkeri* do not live in the lake at the present time. This fauna probably migrated up the St. Joseph River to the Dowagiac River and then up Dowagiac Creek.

3. Pipestone Lake, Berrien County

In the northeastern part of Berrien county, near the Van Buren county line, is another lake of about the same area as that of Magician Lake. This body of water drains into the St. Joseph River through Pipestone Creek. Marl beds similar to those of Magician Lake occur in Pipestone Lake, and have yielded a number of species of mollusks as indicated below:

Sphaerium simile (Say)
Sphaerium striatinum (Say)
Pisidium compressum Prime
Pisidium variabile Prime
Pisidium splendidulum Sterki
Valvata tricarinata Say
Amnicola limosa parva Lea
Amnicola lustrica Pilsbry
Physa integra Hald
Physa heterostropha Say
Planorbis trivolvis Say
Planorbis antrosus Conrod
Planorbis antrosus angistomus Hald
Planorbis antrosus striatus Baker
Planorbis campanulatus Say
Planorbis deflectus Say
Planorbis hirsutus Gould
Planorbis parvus Say, many monstrosities
Galba obrussa decampi (Streng)
Galba obrussa exigua (Lea)
Lymnaea stagnalis appressa Say.

These mollusks evidently migrated to Pipestone Lake either by way of the Chicago outlet, the St. Joseph River and Pipestone Creek, or up the Kankakee and St. Joseph rivers. It is probable that both routes contributed to the formation of both of these small lakes.

My thanks are due to Dr. Bryant Walker of Detroit, Michigan, and to Dr. V. Sterki of New Philadelphia, Ohio, for assistance in identifying critical material.

THE PHYSIOLOGICAL AGREEMENT AMONG THE ANIMALS OF ANIMAL COMMUNITIES

BY V. E. SHELFORD, UNIVERSITY OF ILLINOIS

All the animals occupying a relatively uniform habitat constitute an animal community. A physiological agreement exists among the animals of communities. The object of this investigation was to determine the extent and character of such agreement with particular reference to the rapids community of a large creek. Considering the community as a whole there is

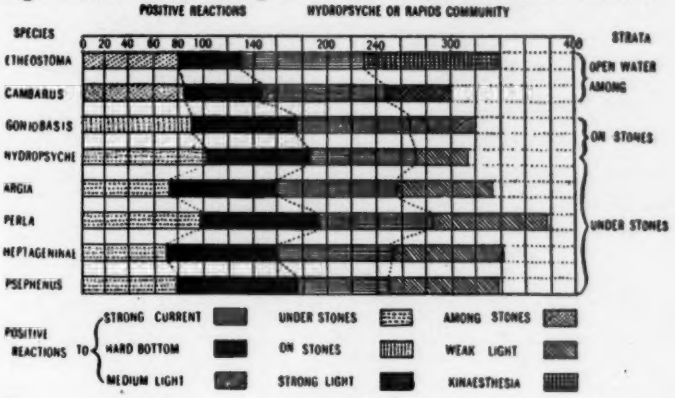

Figure 8
Biol. Bull. Vol.. XXVI, p. 313. Fig. 40.

(1) a *general agreement* in reactions to certain factors; (2) *disagreement in respect* to factors differing in intensity vertically, and (2) *a sharp difference* between *the rapids community* and other communities.

Figures 8 and 9 are introduced to show the character of the agreement and disagreement in a rapids community, and the fact that the pool community is different but remains unsolved. Noting first figure 8, we note a noteworthy agreement in reaction to bottom and to current. The preference for hard bottom in these experiments means the avoidance of sand as sand and hard bottom were present in the experiment. Animals living under stones were under stones in darkness in the experiment. The snail (*Goniobasis*) which lives on stones was found on stones in the experiment. The darter (*Etheostoma*) and the crayfish (*Cambarus*) which live among stones were found among stones in the experiment. Thus the different animals differ in their reactions to bottom and are in disagreement with reference to their vertical distribution in nature. Turning to reactions to light we find a comparable difference.

Animals living beneath stones show a preference for weak light, those living on stones, medium light, those among stones, strong light. If we were to study the community in full we would find that reactions to many other factors are of importance.. Associative memory no doubt plays a role. Thus there

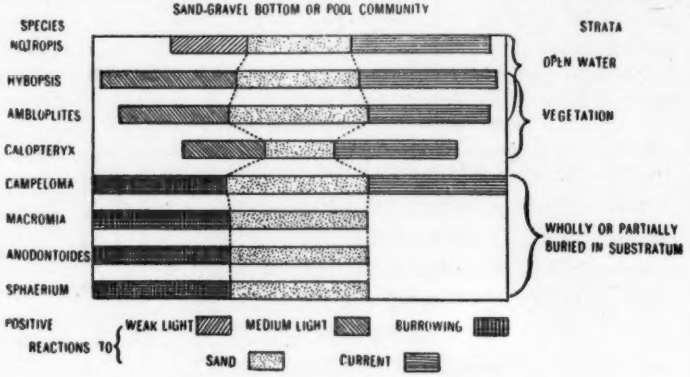

Figure 9
Biol. Bull. Vol. XXVI, Fig. 4, p. 314.

is agreement in reaction to factors of prime importance in the community habitat as a whole and disagreement in respect to factors differing strikingly in the different situations in which the animals live within the community habitat.

The diagram of the pool community, Fig. 9, is introduced to show how strikingly it differs from that of the rapids community. Though agreement is not indicated here on account of the incomplete character of the experiments, our experience with the reactions of pool fishes and invertebrates to chemical differences in water, suggests that such differences may be of much importance to all the species. The difference between the two communities is emphasized by the presence of a strong preference for sand bottom and by the presence of the burrowing habit, both of which are wanting among the animals of the rapids community. The non-burrowing pool species are positive to current; the burrowing species do not respond within ordinary lengths of time. The reactions to light show much more sharp negativeness than in the case of darters and crayfishes of the pool community. The community is clearly unsolved and a large amount of experimentation would be necessary to determine suitable tests for these animals and then all the animals of both communities should be put through all the tests, new and old. A series of new tests must be added for each new aquatic community and all the old tests must be

so modified as to secure responses from all the animals. Thus the labor involved in comparing a number of communities is great.

DESCRIPTION OF FIGURES

Figure 8, showing the agreement and disagreement of the reactions of the animals of the rapids community. Note agreement of reaction to bottom and current and disagreement in two other reactions related to the level at which the animals live. These results were obtained by placing the animals under experimental conditions in which they had a choice between different kinds of bottom, different strengths of light, and in which their behavior in a water current was noted. In the case of water current the percentage of animals headed up stream is given. When headed up stream animals are said to be positive to current. In the case of the other stimuli the percentage of animals in the kind of conditions available was noted and the animals are said to be positive to the conditions in which the greatest number are found. Thus we note that the darter (*Etheostoma*) was 80 per cent among the stones and is said to be positive to this kind of situation. It will be noted that if the animals had been 100 per cent positive to the various stimuli the entire 400 units should be occupied in the diagram. This could be true only if there were no other factors entering into the reactions of the animals. The common names of the animals are as follows: *Etheostoma,* darter; *Cambarus,* crayfish; *Goniobasis,* snail; *Hydropsyche,* Caddis worm; *Argia,* damsel fly; *Perla,* stone fly; *Heptageninae,* may fly; *Psephenus,* water penny.

Fig. 9. Suggestions as to the probable agreement and disagreement in the reactions of the animals of the unsolved pool community on the basis of a total of 300 per cent. The common names of the animals are as follows: *Notropis,* shiner; *Hybopsis,* river chub; *Ambloplites,* rock bass; *Calopteryx,* damsel fly; *Campeloma,* snail; *Macromia,* dragon fly; *Anodontoides,* mussel; *Sphaerium,* small bivalve.

RECENT VIEWS CONCERNING ELECTRICAL CONDUCTANCE IN SOLUTIONS

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In 1801 Nicholson and Carlysle discovered that solutions conduct, and ever since that time the question as to how they conduct has been more or less of an open one.

Let us first briefly consider two of the older theories of conductance. The first one which we will consider is the theory advanced by Grotthuss. According to this one, the substances existed in the molecular state in the solution. On the passage of the current the molecules first lined up, then split off and then rearranged. This procedure was continued as long as the current was passed. Clausius showed this to be incorrect, for the reason that Ohm's Law holds for liquid as well as metallic conductors, and if this is so, no electrical energy is used up in breaking up the substance, but on the other hand, the ions must already exist in the solution. The reason for a substance break-

ing up on going into solution he ascribed to the collisions due to molecular motion in the solution. Fortunately for Clausius, at the same time Williamson was working on the subject of etherification and came to the same conclusion independently. This theory of Clausius dominated chemistry for many years, in fact until Arrhenius came forward with the one which is familiar to you all. This theory may be stated thus:

When a substance is dissolved in water and conducts the electric current, it is dissociated into ions more or less completely, depending on the dilution, and that the degree of this dissociation may be calculated from (1) the conductance of the solution, (2) the lowering of the freezing point or raising of the boiling point, and (3) the osmotic pressure.

Let us now consider first some of the reasons, in a general way, why this theory is favored, after which we will take up some of the objections, and then consider some of the very recent work.

THINGS IN FAVOR OF THE THEORY

1. Many aqueous solutions conduct and many non-aqueous do not.

2. When a current is passed through a solution of an electrolyte there is an immediate production of discomposition products.

3. Many or most electrolytes show too great a lowering of the freezing point, raising of the boiling point, and too great an osmotic pressure.

4. All or nearly all strong bases when neutralized by strong acids show the same heat of neutralization.

5. The instantaneous interaction of chemicals when electrolytes and the slow or lack of action when they are not.

6. Some gases, when dissolving in water, do not obey Henry's Law.

7. The hindering of a reaction by adding something that will give like ions.

8. Most substances dissociate more as the dilution is increased.

9. Faraday's Law.

OBJECTIONS TO THE THEORY

1. Non-aqueous solutions do conduct.

2. In some solutions the conductivity does not increase on dilution.

3. In some the dilution makes the conductivity increase, some increase then decrease, some decrease, and some decrease then increase.

4. There are instantaneous reactions in non-aqueous solutions.

5. Neutralization of non-aqueous solution does not always give the same heat of reaction.

6. The degree of dissociation as calculated by the three different methods do not always agree.

7. The hindering of a reaction by adding something which does not give like ions.

8. Faraday's Law holds for non-aqueous solutions.

9. The equation for degree of ionization calculated on the basis of concentration does not always hold, even for typical salts.

These are only a few of the reasons, and many more might be given on each side.

Let us now consider some of the recent work, more in detail.

The work of Walden of Rega apparently showed that there was a direct parallelism between the dissociation power as indicated by the conductivity and the dielectric constant. Without a doubt, this was true for the one solute that he used, but it has been equally well established by work done at Wisconsin and by some unpublished work done in our laboratory, that this relation does not hold in all cases.

Creighton of Halifax on the other hand gives results in a recent paper which show that for aniline in acetophenone the Nernst-Thomsen rule does hold. Also Davis of Dalhousie College found the same relations for rosaniline hydrochloride in organic solvents, as Walden did for his solute.

Thornton of the University of Durham, says in explanation of some high values for the dielectric constant obtained for some liquids such as water, that it is an effect depending on the electrical conductivity.

To get his results Walden assumed that the conductivity of the solvents which he had especially purified was due to ionization. This is likely not the case for the reason that the conductivity is dependent upon the mode of purification. In this connection I will recite the recent work of Corvallo, published in C. R., in which he states that he obtains ether so pure that its conduction is very likely due to impurities.

Viscosity is recognized as having considerable influence on the conductivity of a solution. Lloyd of Alabama has recently showed that he gets entirely different maxima at 50° C. than he does at 100° C. for the same solutions, and this difference he attributes to changes in viscosity. Pratolongo of Milan determined the conductivity of a solution of citric acid with hydrochloride, arsinous, or phosphoric acids dissolved in it, and found that each addition reduces the specific conductivity. This effect is ascribed in part to an increase of the viscosity of the solution by these additions.

Some very interesting results have been obtained by the prolonged passage of an electric current through ammonia or

ethyl alcohol, when it was found that the conduction increases with the length of time of the passage of the current. Methyl alcohol does not behave in a like manner. This work was done by Corvallo and published in C. R. 156.

The work of Kahlenberg of Wisconsin with instantaneous precipitations of anhydrous copper chloride from anhydrous copper oleate solutions by means of a dry solution of hydrochloric acid in benzene is doubtless familiar to you all. These solutions are all non-conductors and the resulting liquid with the precipitate in is a non-conductor. However, recent work by Cady and Lichtenwalter of Kansas has shown some interesting things in this connection. To take a typical example they passed dry hydrochloric acid gas into copper oleate solution, and while neither one alone was a conductor, nor was the resulting mixture a conductor, they found that just previous to the precipitation, which they say was not instantaneous, that the liquid showed considerable conductivity. At this time I do not care to comment on this work further than to say that it seems to throw light on one of the apparent exceptions to Arrhenius' theory.

The state which a substance is in, apparently has considerable influence on whether the solution conducts or not, even in organic solvents. This was shown by Lloyd of Alabama, who found that when Molybdenum pentachloride is dissolved in an organic solvent giving green solutions, that they have a conductivity of the same order as water solutions of common salts. Differing in this respect, however, that the molecular conduction decreases with dilution. When this same salt dissolves, giving red-brown solutions, they do not conduct appreciably.

With these few considerations, I want, in a way, to ask your pardon for the disconnectedness of the material presented, which, however, is rather forced on the writer by the disconnectedness of the views.

CYCLONIC DISTRIBUTION OF WEATHER ELEMENTS FOR DAVENPORT, IOWA.

ANTON D. UDDEN, AUGUSTANA COLLEGE

The daily weather forecasts issued by the United States Weather Bureau stations are largely based upon the easterly progress of successive areas of high and low pressure across

Figure 10. Number of Observations in each tract.

the continent. The accuracy of the predictions depends upon the determination of three factors, namely: the probable path of the cyclone or anti-cyclone during the next twenty-

four hours; its probable translational velocity; and the *distribution* of the meteorological elements within the highs and lows.

The purpose of this paper is to describe some of the results obtained from a statistical study of the distribution of the weather elements for Davenport, Iowa. The present work is based upon a method of study devised by Dr. J. A. Udden and described by him in a paper entitled, "On the Cyclonic Distribution of Rainfall."*

The plan consists in constructing a hypothetical cyclonic area

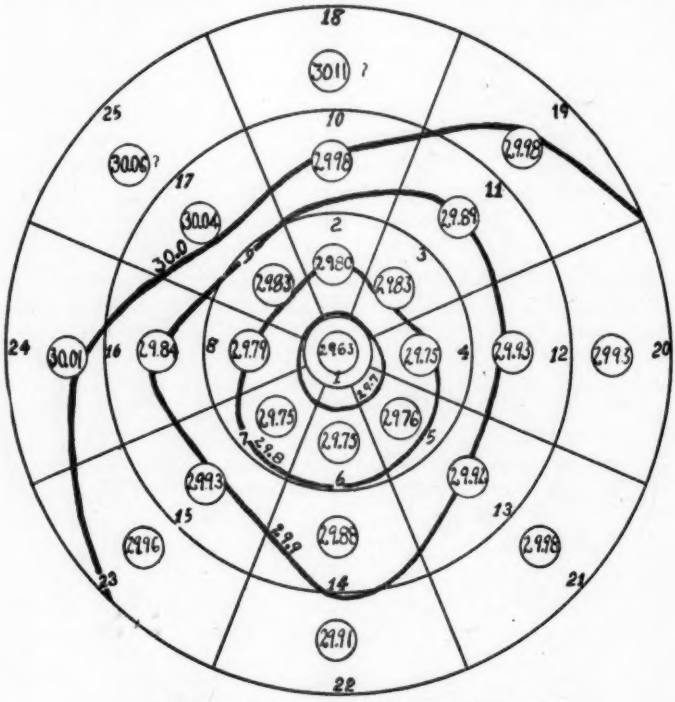

Figure 11. Barometric Pressure

as shown in Fig. 10. Four concentric circles are drawn whose radii measure respectively 100, 400, 700 and 1000 miles in length. Eight radii 45 degrees apart and extending from the outer to the inner circle delimit 25 tracts within the hypothetical cyclone. These are numbered from 1 to 25 in the figure.

*Augustana Library Publications, No. 4, Denkman Memorial Library, Rock Island, Ill.

The next step is simply to determine from a weather map the particular tract of the cyclone in which Davenport lies and to record the simultaneously existing weather conditions. By obtaining a sufficient number of observations it is possible to ascertain the average weather conditions when Davenport is situated in any given area of the cyclone.

The present study is based upon an examination of the

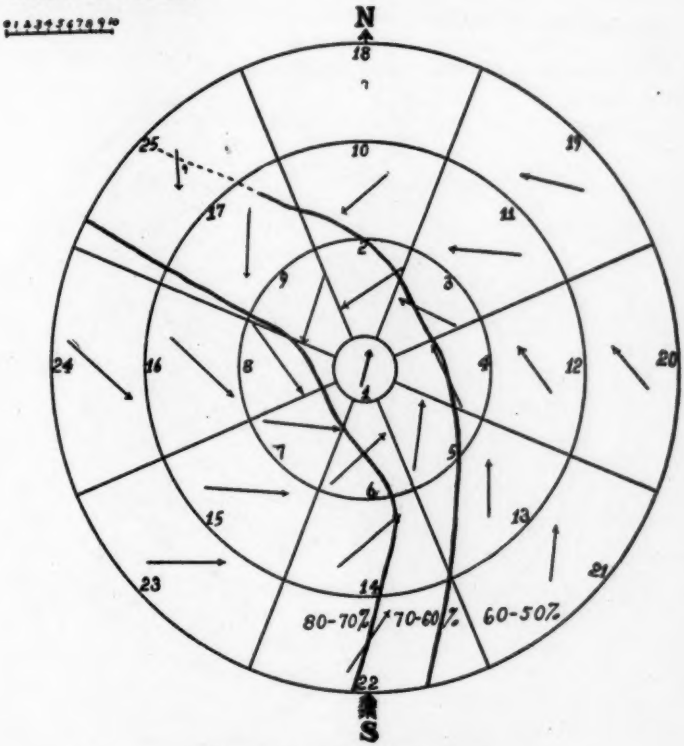

Figure 12. Wind Direction

morning and evening weather maps for a period of about twenty years. A total of 4508 observations have been secured. These are distributed unequally among the 25 tracts of the hypothetical cyclonic area as seen in Fig. 10. The maximum number of observations, namely 521, occurs in tract 15; in this position Davenport lies about 550 miles southwest of the center of the low. The fewest observations, 17 in number, are found in

tract 18, when the center of the low occurs over the Gulf coast. The number of observations in each area is sufficient to give a fairly reliable average of the weather conditions in all tracts except 18 and 25. For this reason the averages in these tracts have been checked by a question mark in the accompanying diagrams.

The number of observations given in figure 10 also show that the center of the low passes north of Davenport about

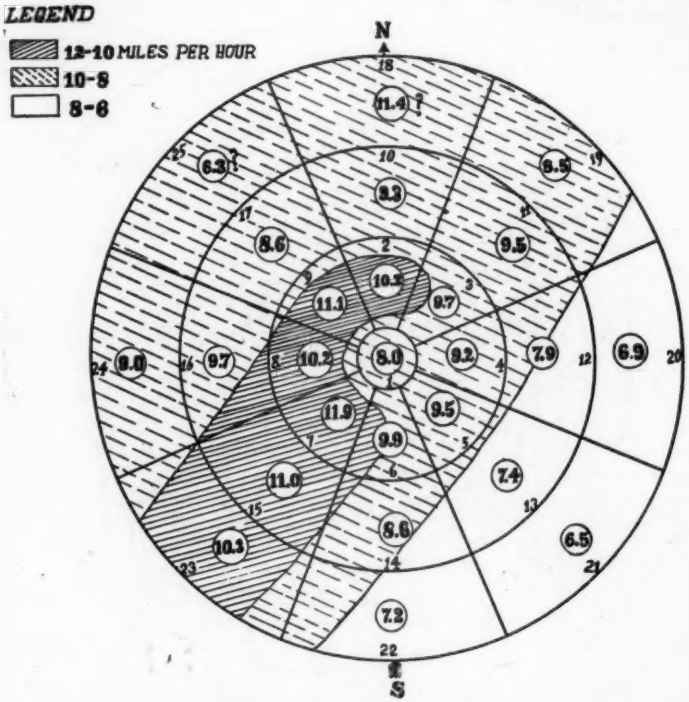

Figure 13. Wind Velocity

twice as frequently as to the south. It passes east and west of the city with about equal frequency. These results evidently depend upon the location of Davenport with reference to the storm tracks traversed by the cyclones.

The distribution of the barometric pressures is shown in figure 11. The numbers within the circles give the average pressure in inches for each tract. The heavy concentric lines represent isobars which conform to the pressure values. In

general the pressure decreases radially toward the center. At the same time it is also evident that the pressure gradient is steepest in the northwest and less toward the southeast. The pressure distribution has a direct bearing on some of the results presented below.

The arrows in figure 12, indicate the prevailing wind directions in the various tracts of the cyclone. They exhibit the general spiral motion of the wind characteristic of cyclones. Upon nearing the center the winds deviate increasingly toward the right. The wind direction in the central tract possesses a southwesterly component of motion. The lengths of the ar-

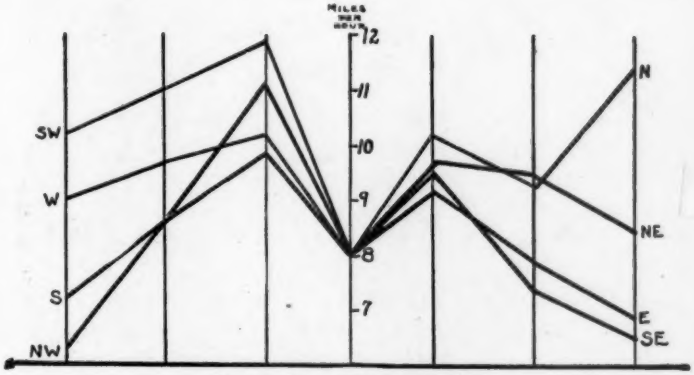

Figure 14. Wind Velocity

rows in figure 12 are proportional to the relative persistence or constancy of the wind in the average direction. The constancy of the wind shows two distinct variations. It increases radially inward to a maximum and drops to its lowest value at the center. This variation is evidently due to a similar radial variation of the wind velocity shown in figure 13. The greater inertia of the higher wind velocities renders them less liable to be deflected by accidental causes. Secondly, the constancy of the wind is greatest in the southwest and decreases toward the northeast. This is shown in figure 12, by the three areas embracing wind directions whose constancy values are, respectively 80-70 per cent; 70-60 per cent; and 60-50 per cent. The high constancy of the wind direction in the southwest is probably due to several causes; the uninterrupted sweep of the wind over the level western prairies; the high wind velocity in this region as shown in figure 13; and

to the relatively stable temperature conditions. The low constancy value in the east and northeast may be accounted for in a similar manner. The presence of the Great Lakes would probably increase the variability; the average wind velocity is low; and the prevailing high temperatures in the east and southeast would introduce an unstable element. (The data in this paragraph are based only on the A. M. observations.)

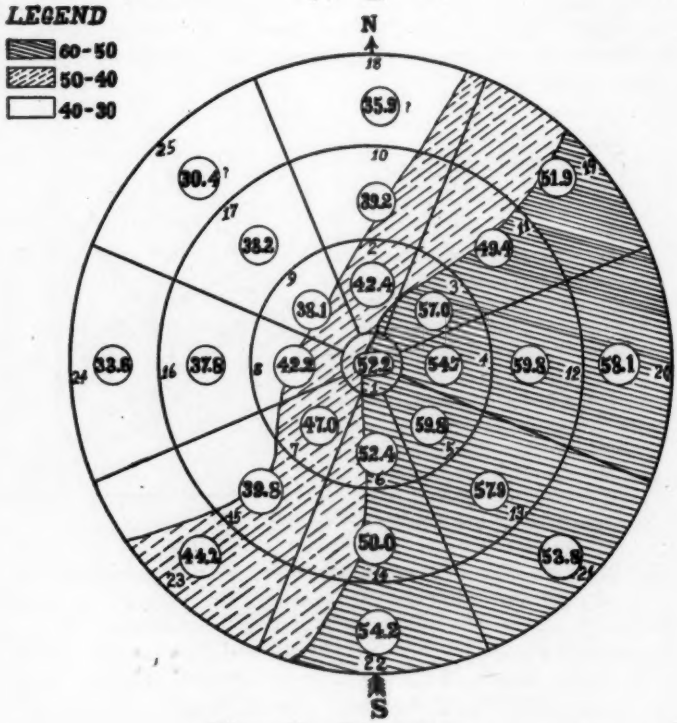

Figure 15. Temperature

The distribution of wind velocities within the cyclone is given in figure 13. The average wind velocity in miles per hour for each tract is indicated by the number inscribed in the small circle. The variation in wind velocity may be separated into two components. First: the shaded areas show that the higher wind velocities prevail in the west and northwest while the lower velocities occur to the southeast of the center. This condition is a direct consequence of the pressure distribution

previously described. The high wind velocities in the southwest are probably due to the coincidence in direction of the prevailing westerlies with the westerly cyclonic winds of these tracts. Secondly, the wind velocities increase radially inward to a maximum and drop to a common minimum at the center. This is illustrated more clearly in figure 14, in which the wind velocities are plotted as ordinates. The abscissa is a diameter of the hypothetical low and the ordinates have been erected at

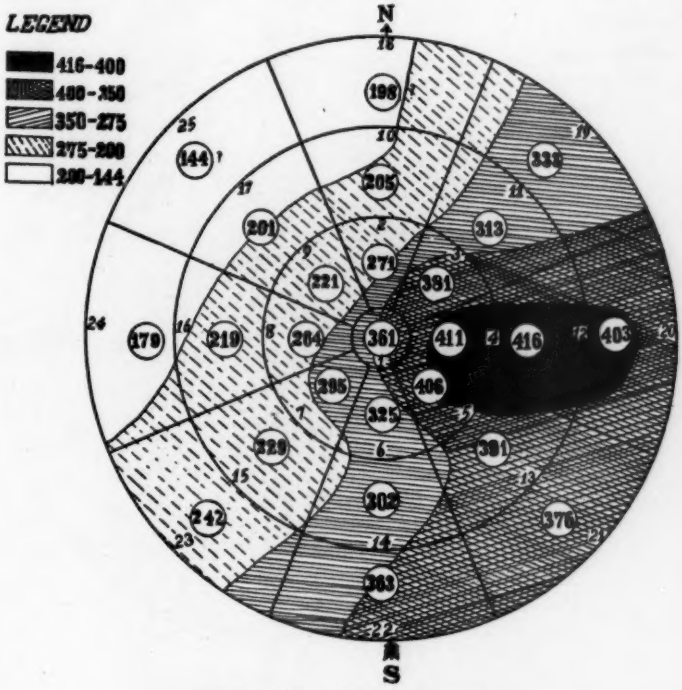

Figure 16. Vapour Pressure

points corresponding to the centers of the tracts along the diameter. A scale of wind velocities in miles per hour is marked off upon the central ordinate. The broken lines indicate the respective radial variations in wind velocity. It is seen that the velocity increases radially to a maximum at the innermost concentric area and then falls to a minimum of 8 miles per hour at the center. These facts are in agreement with the general knowledge of the nature of cyclones.

The distribution of temperatures within the cyclone is shown in figure 15. The average temperatures for the various tracts are inscribed within the small circles. The temperature distribution is also represented graphically by the shaded areas which enclose temperatures ranging from 60-50, 50-40, and 40-30 respectively. The highest temperatures are seen to prevail in the southeast quadrant of the cyclone. This is due to the southerly direction of the winds in that region. The low tempera-

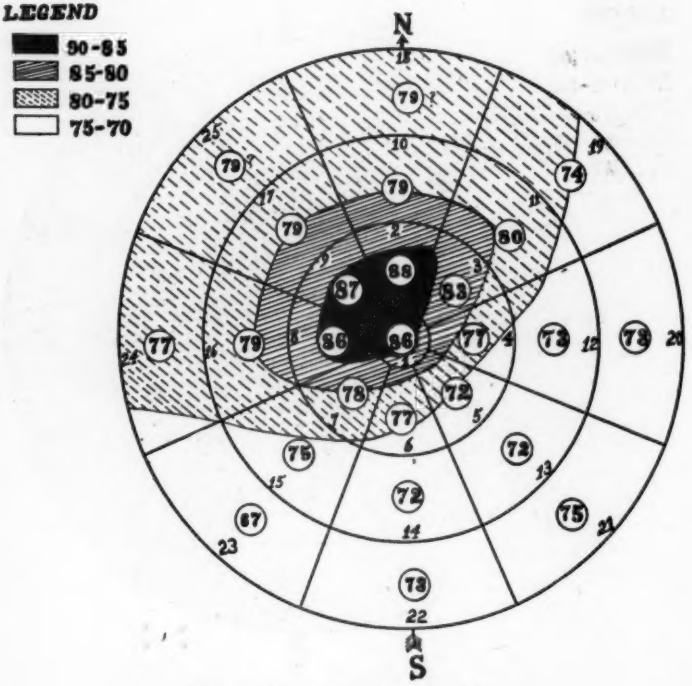

Figure 17. Relative Humidity

tures in the northwest are produced by the cool winds from the north.

The distribution of vapour pressure is similar to that of the temperature. This is seen by comparing figures 15 and 16. The vapour pressure is greatest in the southeast and least in the northwest. The vapour pressure also increases radially toward the center. The similarity of the vapour pressure and temperature distribution is a necessary consequence of the fact

that the vapour pressure varies directly with the temperature although not at the same rate.

The distribution of the relative humidity, amount of cloudiness and frequency of precipitation are shown in figures 17, 18 and 19 respectively. The relative humidity is expressed in per cent; the amount of cloudiness is given in the usual scale of 1 to 10; and the frequency of precipitation is also expressed in per cent. The three diagrams are strikingly similar. On the whole it is seen that the values of these three quantities

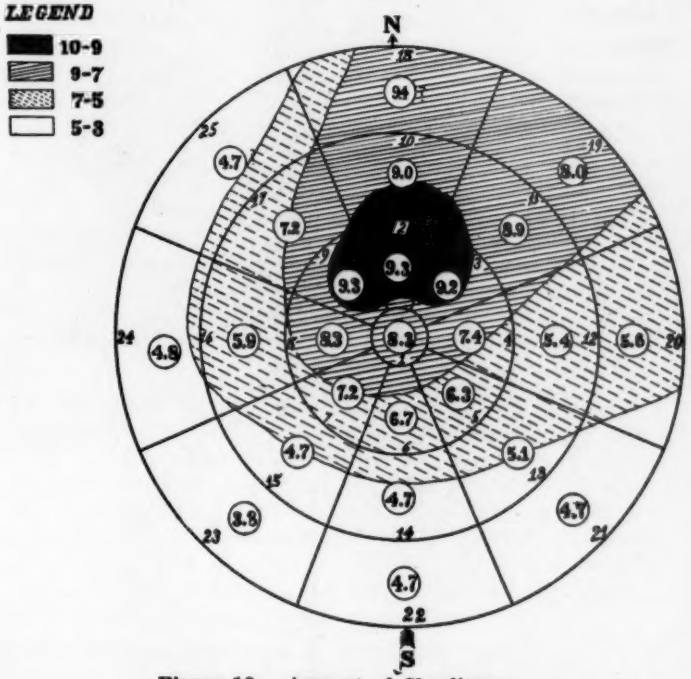

Figure 18. Amount of Cloudiness

are greater in the northern half of the cyclone than in the southern half. The lowest values occur farthest to the southeast of the center. The highest values are found in the dark areas immediately north and slightly west of the center of the cyclone. These areas are relatively small and sharply defined. Judging from the close coincidence in the distribution of the relative humidity, amount of cloudiness and frequency of precipitation, it appears safe to assume that the amount of precipitation fol-

lows a similar distribution. These results seem to stand quite at variance with the statements sometimes found in elementary textbooks on meteorology to the effect that the values of relative humidity, amount of cloudiness and precipitation are highest to the east and southeast of the center of the cyclone.

Several factors probably contribute to the location of the areas of greatest relative humidity, cloudiness and rainfall north of the center of the low. Local conditions evidently of-

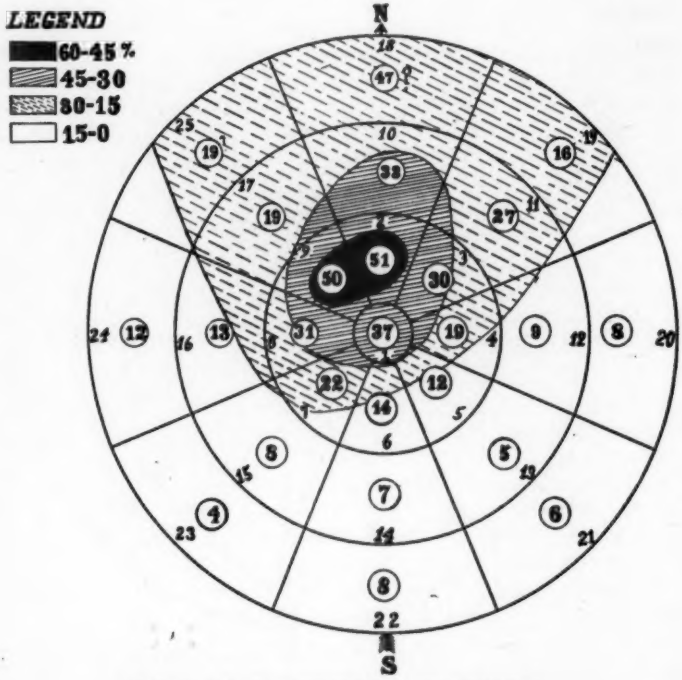

Figure 19. Frequency of Precipitation

fer an important modifying influence. The presence of the Great Lakes to the northeast of Davenport probably constitutes an important cause, also the presence of numerous small lakes, and rivers in Wisconsin and Minnesota. The humidity of the winds sweeping over these areas is probably increased by an appreciable amount. Furthermore the Great Lakes and other bodies of water would tend to decrease the temperature of the northerly winds in the summer time, thus raising the

relative humidity. In the winter time the warmer temperature of the lakes might contribute to the general upward motion of the air in cyclones with the consequent adiabatic cooling.

That the presence of smoke bears a direct relationship to cloudiness seems now to be an established fact. Such a relationship appears to be suggested in figure 18. It is seen that the distribution of maximum cloudiness trends toward the northeast. The action of smoke as a factor in producing this may be stated as follows. Large volumes of smoke are poured into the atmosphere by such manufacturing cities as Gary, Chicago, Milwaukee, Minneapolis and many other cities lying roughly within a quadrant northeast of Davenport. From the figure it is seen that the maximum amount of cloudiness occurs in Davenport when the city is so situated that it lies in the path of the winds blowing over the smoke producing area. On the other hand the quadrants northwest, southwest and southeast of Davenport are relatively free from smoke and the amount of cloudiness registered at Davenport when the winds come from these regions is comparatively low. In order to be reasonably certain that the matter here presented is a real cause of cloudiness it would be necessary to actually count or estimate by an appropriate method the number of particles of dust carried by the atmosphere with the wind from the various directions.

In the preceding paragraphs the author has described in part the cyclonic distribution of weather elements for Davenport, Iowa. The topics considered include: The barometric pressure; wind direction; wind velocity; temperature; vapour pressure; relative humidity; amount of cloudiness and the frequency of precipitation. It is believed that the data here presented are sufficient to show the character and to some extent the value of the method employed, and justify a further application to the method of other localities.

The present description is incomplete. Other matters receiving attention are: the distribution of the various kinds of clouds, thunderstorms, the direction of the higher air strata and the seasonal distribution of the elements. The anticyclones are being studied in a similar manner. The results of a more complete survey of the problem will be given in a later paper.

In conclusion the author wishes to acknowledge with gratitude the assistance received from several sources. Mr. J. M. Sherrier, Local Forecaster at Davenport, Ia., has offered helpful suggestions and courteously given access to the records of

that station. Through the kindness of Major H. B. Hersey, official in charge, local office, Chicago, Ill., the author was permitted to examine the evening weather maps of that office. Special thanks are due Mr. C. W. L. Johnson, who has given valuable assistance in the statistical work.

WATER SUPPLY CONTROL AT EVANSTON, ILL.

W. LEE LEWIS, NORTHWESTERN UNIVERSITY

Whenever a village emerges as a city, it inherits three large sanitary problems, milk supply, water supply and sewage disposal. The difficulty encountered in the solution of these problems depends upon the size and location of the city. In general, it may be said that as a population thickens throughout a country, these problems became more difficult of solution. Their importance to the health of the community is no longer underestimated. It used to be accepted that sickness was more or less of a visitation, to be awaited and endured with patience and fortitude. With the germ theory of disease, and the modern science of Public Health, contagious diseases have been brought to the correct responsibility. This new attitude finds expression in such a statement that "whenever a death occurs from typhoid, someone ought to be hung." When you consider that typhoid bacilli can live no where save in the human intestinal tract for any considerable period of time, the criminal aspects of the spread of this disease are more apparent.

As a society, we have not yet solved our problem of milk supply, else why the annual toll of sickness and death in every city directly traceable to this source? The solution will probably never come so long as milk delivery is in the hands of competition. Too much altruism is called for. Evanston's milk supply is far above the average and an ordinance soon to come before the City Council will make the control still more rigid.

Our local sewage disposal problem is an interesting commentary on "how not to do it." A great drainage canal defaces our outlying districts designed to carry sewage of this and nearby communities down to someone else. State, governmental and international complications point to the inadequacy of this measure as a permanent solution. Complications have moved faster than construction, and the prospects are that this dilution method of sewage disposal for this community will

have survived its period of usefulness before it is ever employed.

The City of Evanston believes she has solved her water supply problem, with the completion in June of the new $225,000 filtration plant. Meantime, the city water is rendered safe by chemical sterilization. The steps that have led to these results may not be without interest and a certain moral.

It has been obvious to many for a number of years that the local water supply carries sewage contamination. A mere physical survey of the situation makes this probable. From the south line of the City of Evanston to the north line of the City of Glencoe, thirteen main sewers pour the drainage of a population of 40,000 into Lake Michigan. The Evanston intake lies in 35 feet of water one and a sixteenth miles from the shore. Knowing that typhoid bacilli can live from one day to a week in lake water and with capricious currents at play, a vicious circle is most possible. Chemical and bacteriological tests repeatedly confirm this. Furthermore, before the chemical sterilization of the water, Evanston, with about the same sources of food and milk supply as Chicago, with superior sanitary advantages and a select population, maintained for a number of years a typhoid death rate from two to three times that of Chicago.

COMPARISON OF DEATH RATES FROM TYPHOID PER 100,000 IN EVANSTON AND CHICAGO

Year	Evanston	Chicago
1907	21	17.5
1908	32	15
1909	28	12.5
1910	24	13
1911	28	10.8
1912	13.8	10.5
1913	13.3	10.5

An investigation of a hundred Evanston cases in 1911 showed that 90 per cent of the victims were users of raw city water. The distribution of these cases by months showed a larger number of cases in the winter months. In sanitary science, this is a recognized index of water-borne typhoid. The situation became acute when in November and December, 1911, Evanston, with a population of 30,000, was averaging over a case a day.

At a cost of $750.00, and on short notice, a "Hypo" sterilization plant was installed, December 25th, 1911, at the Pumping Station, and within two weeks, the mild epidemic was checked. Since that time the rate has been maintained near

the normal residual typhoid rate for this district. Moreover, our cases now occur mostly in the summer and autumn, the period when vacation typhoid, finger and fly typhoid, etc., are operative. This is borne out by the following chart:

TYPHOID CASES BY THE MONTH—EVANSTON

Year	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Cases	Total Deaths
1910	7	8	19	4	5	4	4	5	3	3	2	0	69	6
1911	4	1	1	0	3	0	4	2	4	9	22	49	99	7
1912	12	9	2	4	1	2	1	0	5	17	7	4	64	4
1913	0	1	1	1	3	4	2	1	6	8	3	0	30	4

Year	Cases per 100,000	Deaths per 100,000
1910	276	24
1911	396	28
1912	224	13.8
1913	100	13.3

Enteritis is recognized as a disease rather closely associated with a contaminated water supply. The following table summarizes the deaths from this cause for the past seven years.

EVANSTON DEATH RATE PER 100,000

Disease	1907	1908	1909	1910	1911	1912	1913
Enteritis	45	20	52	48	32	12	37

While there is a notable falling off in 1912, there is a return to near former rate from this disease in 1913. This is possibly explained by the fact of a higher mortality rate, especially among infants during the unusually hot summer of 1913. A higher rate with a greater percentage of cases among young children would in itself rather point to food supply as a source of the infection.

It is fully recognized that too much reliance cannot be placed upon statistics gathered from a population of 30,000 people, yet a fair examination of all the data seems to confirm the experience of many large cities in respect to water borne diseases before and after improvement in the water supply.

If Hazen's theorem is correct, namely, that for every death from water borne typhoid, there are three or four deaths from other diseases attributable also to contaminated water, the above improvement in the typhoid rate has still greater significance to the community.

Recognizing the conclusive evidence of sewage contamination of the city water, a bond issue for $200,000 was voted by a large poll in the fall of 1912.

This plant, now near completion, is of the mechanical gravity type equipped with mixing tank, settling basins, six independent two million gallon filter units and two 1¼ million

gallon storage reservoirs. It is located just north of the University campus on land given by Northwestern University. The plant is built so as to use the present pumping station, and with the exception of the operating building, will be sodded over and covered with shrubbery.

The "Hypo" Treatment Plant being used in the meantime has been maintained without additional labor and with a cost for chemicals of about 25c per day. The plant consists of a mixing machine for making the "Hypo" into a thin paste with water. The mixer is set so that the overflow drains into two wooden tanks, eight feet in diameter and three and one half feet deep. The mixing and dilution tanks, arranged in pairs and used alternately, drain into a two-inch wrought iron pipe. Power for mixing and stirring the dilution tanks is furnished by a Pelton wheel. The dilution tanks are set about three feet above the floor and are tapped on the sides about two inches in the clear above the bottom, with ¾ inch galvanized iron pipe. The piping leads to an orifice box and is so arranged that the solution can be drawn from either tank or both tanks at once. The orifice box sets on the floor of the well house and feeds into ¾ inch galvanized iron pipes leading to the grids. Below the orifice box, a valve is set and below this valve a T through which a pressure pipe is connected. The grids consist of ¾ inch galvanized iron pipes, Ts and plugs, each lateral pipe having two ¼ inch holes drilled in and placed on the down stream side of the pipe. One grid is placed over the top of the shaft, the other in the 36 inch T at the side of the well. By placing the grids at these points, the water is treated when it enters the well, and has about twenty minutes contact before reaching the suction of the pumps. At present 50 pounds of the chemical are being used with 1,420 gallons of water. After this mixture has been thoroughly stirred in the dilution tanks, it is allowed to stand for at least one hour before being drawn off. Considerable insoluble matter is always present which would otherwise cause stoppage in the orifice box and valves.

Each gallon of the above solution contains .0352 pound of hypochlorite, analyzing 37 per cent available chlorine. From the following formula, the engineer operates his orifice box:

N=No. of gallons pumped per minute.

$$\frac{1{,}000{,}000}{N} = M$$ **or number of minutes to pump 1,000,000 gallons.**

Q=No. of pounds of "hypo" to be added to each 1,000,000 gallons.

$\frac{Q}{M}$ = P. or pounds of Hypo to be added each minute.

$\frac{P}{.0352}$ = No. of gallons of liquid to be added per minute.

When any considerable variation in the speed of the pumps is noticed by the engineer, he counts the revolutions and determines the pumpage. The number of gallons of solution to be added is then calculated and from a chart furnished by the manufacturers, the orifice box is set.

The amount of chemical used during the past two years has varied from three to ten pounds per million gallons. There has been some complaint of the odor and taste, but the city accepts the situation as a desirable temporary measure.

ON THE CONDITIONS UNDER WHICH THE VEGETABLE MATTER OF THE ILLINOIS COAL BEDS ACCUMULATED

BY T. E. SAVAGE, UNIVERSITY OF ILLINOIS

All students of the subject agree that coal was derived from vegetable material which has undergone imperfect decomposition without free access of air. The complete explanation of the coal beds involves, among other things, an explanation of (1) the method and conditions under which the plant material accumulated; (2) the kinds and proportions of the different plants that contributed the vegetable material; and (3) the physical and chemical changes by which the plant tissues were transformed into coal. The first part of the problem with regard to the method and the conditions under which the vegetable matter of the coal beds accumulated can be studied somewhat independently of the other two, and the solution should be found in the structural features of the coal beds and associated strata.

Two important theories have been proposed to explain the mode of accumulation of the vegetable matter of coal beds. The older of these, known as the "transport of driftage" theory, assumes that the vegetable materials grew on land areas, whence they were carried by streams and deposited in the bodies of water where they accumulated. The other, known as the "swamp, or growth-in-place" theory was suggested in 1778 and assumes that the vegetable matter of coal beds ac-

cumulated in swamps practically in the places where the plants grew.

The following facts presented in the principal coal beds of Illinois make impossible the application of any form of the transport theory of accumulation of the vegetable material: (1) the great extent of the coal beds—the Herrin (No. 6), and Springfield (No. 5) beds were deposited in practical continuity over at least 7000 square miles, and probably over a considerably greater area in the state; (2) the regularity of thickness of the coals—the Herrin (No. 6) bed ranges from 7 to 9 feet over a known area of at least 5,000 square miles. A thin band of shale or shaly coal (blue band) one-half to two inches thick, is present 18 to 24 inches above the floor of this coal over practically the entire area of its distribution, and the thickness of the benches above and below the "blue band" is remarkably uniform. The Springfield (No. 5) bed, also scarcely varies one foot in thickness over more than 5,000 square miles. (3) The small percentage of mineral matter or ash in the coal shows that very little mud and sand sediments were mixed with the plant remains as they accumulated.

In time of flood the amount of mud and sand carried by streams is so great compared with the amount of vegetable matter, and the latter is deposited so irregularly, that it can scarcely be imagined how the plant material of these coal beds could have been carried by streams into the Illinois basin, and have accumulated in practical continuity over such extensive areas, in anything like such uniform thickness, and with so little mingling of mineral sediments. Extensive areas of relatively pure vegetable matter are known to be accumulating in swamps at the present time, but there is no known place where plant remains transported by streams during floods are accumulating as a continuous bed over any considerable area, in anything approaching uniformity of thickness, and without a very large mixture of sand and mud; nor does it seem probable that pure transported vegetable deposits have ever accumulated over any considerable area in the past.

From a study of small coal basins of France in recent years Fayol, supported by DeLapparent and other French geologists, has revived the transport theory of accumulation of the vegetable matter of coal beds. However, practically every geologist who has studied extensive coal beds, especially those of the Appalachian region of the United States with which the coal beds of Illinois are comparable, has rejected the transport theory of accumulation as applied to those beds. Rogers

Brothers, Lesquereux, Dawson, Andrews, Dana, Orton, Stevenson, White, and Ashley, have all accepted the growth in place theory of accumulation of the vegetable matter of extensive coal beds as the only one that is consistent with the facts. It is safe to assume, then, that the vegetable matter of the coal beds of Illinois accumulated practically in the places where the plants grew.

The acceptance of the growth-in-place theory of accumulation does not settle the question whether the basins bordered the sea, as lagoons, or occupied broad depressions over coastal plains, as the Dismal Swamp, or covered large areas over river flood plains; nor is it purposed to discuss this phase of the question at this time. The fact that the vegetable matter of coal beds accumulated under water in the places where the plants grew does not prove that the water was ever more than a few inches, or at most a very few feet in depth, even where coal beds 5 to 10 feet thick have been formed. On the contrary the structural features of the coal beds indicate conclusively that the water in which the vegetable matter accumulated was very shallow as well as that it was very quiet.

STRUCTURAL FEATURES OF THE COAL BEDS

One of the more conspicuous structural features of the coal beds of Illinois, which are representative of the larger beds everywhere, is their stratification, the more prominent bedding planes being 3 to 5 or more inches apart. These bedding planes form partings along which the coal separates rather easily, and they usually show well-developed bands of "mother coal," or mineral charcoal. These stratification planes often become more conspicuous when the bed is weathered, but some of them are prominent on unweathered faces. Such a conspicuous clean parting of mineral charcoal occurs 18 to 24 inches below the roof of the Herrin (No. 6) coal over several hundred square miles in western and southern Illinois, and appears to be almost co-extensive with that bed. Along this charcoal zone, the coal separates so perfectly that where the overlying shale does not stand well in the mines the coal above this parting is left for a roof. Five or six inches lower is another mineral charcoal parting, almost equally well developed and persistent.

Between the more prominent partings and bedding planes, the coal from roof to floor is made up of alternating bright and dull laminae, which are usually ½ to 1-32 of an inch thick, although in places they are considerably thicker. The aggregate dull bands generally make up nearly or quite one-half of

the coal beds, and they appear to be of the same general nature as the bedding planes mentioned above. They are often rather uniform in thickness over considerable areas, but in places they thicken for some distance and in others they thin down to knife-edge partings. When the coal is split along well developed dull laminae the cleavage planes almost always show distinct mineral charcoal surfaces. The bright laminae appear to be quite homogeneous in structure.

The features above described are not peculiar to Illinois coals. H S. Rogers and others have noted the alternations of laminae of bright and dull coal, and the predominance of mineral charcoal in the dull laminae in the coals of the Appalachian region, and the writer has observed the same characters in the coals of Iowa. They have been described from coal beds generally in different parts of the world. The mineral charcoal is so constantly present, and so intimately mingled in, and constitutes such an important part of the dull laminae of the coal that they must have been developed together; in fact, the dull appearance of these laminae in relatively pure coal beds is due for the most part to the presence of mineral charcoal in these bands.

THE ORIGIN OF "MOTHER COAL" OR MINERAL CHARCOAL

Two main explanations have been proposed to account for the origin of mineral charcoal. One of these, held by many paleobotanists and chemists in recent time, explains the mineral charcoal as formed from real charcoal derived from plant tissues which resulted from forest fires sweeping over land areas, the charred fragments being subsequently swept by flooded streams into the basins where they were deposited with the mass of vegetable matter there in process of accumulation.

This explanation assumes that a considerable part of the vegetable matter of the coal was transported material, which assumption is open to all of the objections to the "transport" theory mentioned above. It assumes that a very important proportion of the coal was derived from plant tissues that had been charred by fires previous to their accumulation, and that these charred fragments had been carried into the coal basin by streams in such enormous quantities as to cover the surface of practically the entire area of the present coal beds, 5000 to 8000 square miles or more in extent; that this process took place not only once but was repeated as many times as there are persistent dull charcoal-bearing laminae; requiring scores or hundreds of recurrences of such charcoal deposition

during the accumulation of the vegetable matter of each of the large coal beds. It assumes such a depth of water above the accumulating vegetable matter that the charred fragments brought in by the streams could be freely floated out above the mass of vegetable matter already present, to every part of the basin; and most impossible of all, that the streams that carried such vast quantities of charred vegetable matter carried at the same time little or no mud or mineral sediments. If it is assumed that the water of the basin was so shallow that the clay and sand brought down by the streams were strained out in the meshes of the tangled plant debris near the margin of the swamp, then the same vegetable sieve would catch the charred fragments and not permit them to be distributed to every part of the basin in which the vegetable matter was ac-accumulating. It will be seen that this explanation is not at all in harmony with the facts of the vertical and horizontal distribution of the mineral charcoal bands in the coal beds.

A modification of this view assumes that the mineral charcoal represents partially burned vegetable matter resulting from fires sweeping over the surface of the marshes in which the vegetable matter of the coal beds was accumulating. It is not probable that fires would start from lightning and travel over water-covered swamps with only the living undergrowth and green leaves and branches of the trees to support the flames; and if they did they would not leave such a uniform and thick layer of charred fragments as would be required to form the mineral charcoal that occurs in the well developed dull laminae. If it is assumed that the surface of the vegetable matter that had accumulated in the swamp had been exposed to the atmosphere and partially dried before the fires swept over it; then the general conditions involved would be similar to those under which the mineral charcoal is interpreted as having been formed by the partial atmospheric decay of the upper surface of the vegetable material of the bog exposed during periods of unusual low water, without the action of fires.

It seems to the writer that the explanation of mineral charcoal as resulting from the temporary exposure and partial atmospheric decay at the surface of the vegetable matter in the bog, instead of the assumption that it must have been charred by fire, is much more consistent with the following facts: (1) the frequent repetitions of the dull laminae containing such considerable thicknesses of mineral charcoal; (2) the larger number of plant spores in the dull laminae than in the bright coal; (3) the numerous pinnae and pinnules of

ferns[1] in the midst of the mineral charcoal fragments; (4) the absence of layers of ash that would result from the burning of vegetable matter at the surface of the bog; and (5) the changes that take place in the vegetable matter at the surface of shallow marshes during period of drought and exposure at the present time.

EXPLANATION OF THE BRIGHT AND DULL LAMINAE

In explaining the origin of the bright and dull laminae, Dawson[2] maintained that it was only the outer bark of flattened tree trunks that formed the shining coal. In a recent paper on the origin of bright laminae of coal, Pringle[3] of the Geological Survey of Great Britain, reaffirms Dawson's view.

The serious objection to this view is the fact that the bright and dull laminae of the coal beds are so nearly parallel and are often continuous for long distances. Trees that are overturned in swamps fall in various directions, and their trunks lie across one another at different angles. If only the cortical portion of tree trunks formed the bright laminae of coal, these bright laminae would not be continuous for long distances, and the dull laminae would be broken at short intervals by small areas of bright coal representing the cross-sections and oblique sections of the cortical portions of tree trunks that lay at different angles and at different levels from those that formed the bright bands in any exposure.

Microscopic examination of bituminous coal has shown that spores are more numerous in the dull laminae than in the bright, and hence some geologists have concluded that the dull laminae resulted from the greater number of spores in these bands, while the bright laminae were formed from the more woody portions of the plants. However, a study of the dull laminae shows that, while they may contain spores in greater abundance than the bright laminae, yet they are very largely composed of mineral charcoal which certainly has been derived from plant tissues other than spores.

The alternation and great extent of the bright and dull laminae are such constant features of the coal beds, and the mineral charcoal is so generally present in the dull laminae that any adequate explanation of the origin of these features must involve agencies that were repeatedly operative over practically the entire area of accumulation of the coal beds. The only re-

1, White, David; Economic Geology, Vol. III., 1908, p. 302.
2, Dawson, J. W.; On the Conditions of the Deposition of Coal. Quar. Jour. Geol. Soc., Vol. 22, 1866, p. 141.
3, Pringle, John; On the Origin of Bright Laminae of Coal. Trans. Edinburgh Geo.. Soc. Vol. X., pt. 1, 1912, p. 33.

current agency of such widespread action is change in the water level of the basin during the time the vegetable material was accumulating.

If it is assumed that the dull laminae resulted from the flooding of the basin, we should have associated with the dull laminae a considerable percentage of mud deposited during such times of flood. We are not left to speculate with regard to the effects of flooding of a basin during the progress of accumulation of the vegetable matter of the coal, for we have such an example in the clay band or "blue band" of the Herrin (No. 6) coal, which extends over practically the entire area of its distribution, and is clearly a mud parting due to flooding. Black shale partings common in portions of some coal beds, as in coal No. 1, in Illinois are also records of flooding of the marshes during the time of accumulaton of the vegetable matter. The typical dull laminae and mineral charcoal zones in the large coal beds of Illinois, as elsewhere, are not such mud partings. They usually contain only a slightly, if any, greater percentage of ash than the bright bands, and are practically free from clay silt. They contain a relatively smaller percentage of volatile matter and a larger proportion of fixed carbon than the bright bands. It will be seen from the following table, in which a number of proximate analyses of mineral charcoal are compared with analyses of average coal from the same beds, that in general the mineral charcoal contains only a little if any more ash than the average coal of the bed in which it occurs.

After discussing the original amount and the composition of the ash contained in living species of such types of coal plants as lycopods, ferns and equisetae, Stevenson[1] concludes that "one should expect to find in ordinary (pure) coal not much less than 6 per cent of ash, or even more, in which silica and alumina should predominate greatly." He thinks it probable that coals containing less inorganic matter than the plant substance should have yielded, have had some of the original inorganic content removed by solution in ground water. It is probable that some coals which locally contain more than the original amount of inorganic matter, as pyrite lenses, etc., have been situated in places favorable for deposition of minerals rather than solution, and in this way have become enriched in their mineral content. In many places also a small percentage of the inorganic constituents of the coal above that originally present in the plants, may have come from wind-blown dust

1, Stevenson, J. J. The Formation of Coal Beds; Proc. Am. Phil. Society, vol. LII., 1913, p. 107.

TABLE I.

PROXIMATE ANALYSES OF MINERAL CHARCOAL AND OF AVERAGE COAL FROM THE SAME SEAMS

(a) Charcoal samples; (b) Average.

	Water	Volatile Matter	Fixed Carbon	Ash	Ash in charcoal above or below that in average sample.
1a	1.17	19.77	72.13	6.93	+4.69
1b	1.94	39.26	55.83	2.24	
2a	.75	20.36	71.07	7.82	+3.04
2b	1.37	37.80	54.46	4.78	
3a	2.39	12.40	75.34	9.87	+4.20
3b	1.68	34.97	57.00	5.67	
4a	.52	14.32	64.03	21.13	+3.92
4b	1.04	28.01	49.24	17.21	
5a	.55	9.92	81.37	8.16	—1.97
5b	.85	16.85	69.58	10.13	
6a	.85	8.35	87.64	3.15	—2.18
6b	1.19	20.76	71.70	5.33	
7a	.57	20.98	70.37	8.08	—2.52
7b	.77	17.11	70.74	10.60	
8a	.85	10.49	84.01	4.65	—3.74
8b	.95	17.85	72.15	8.39	
9a	1.58	23.96	64.28	10.18	— .54
8b	.94	17.85	72.15	8.39	

Nos. 1-8. Analyses by McCreath, second Geological Survey of Pennsylvania. Vol. MM, pp. 1-107; Moisture at 225 degrees F.

No. 9, Analyses Ill. Geol. Survey, Herrin (No. 6) coal, Williamson County, Illinois; Moisture air dried.

that settled over the coal basin during the long period of accumulation of the vegetable matter. The amount of ash in a coal bed varies very considerably at different levels and in different places even in the same mine. Among the possible causes of such variation are differences in the proportions of the kinds of plants that formed the coal, removal and deposition of mineral matter by ground water, and wind-blown dust. Hence, in the absence of definite evidence of sediment contributed by water, such as black shale or mud partings, it is thought that, as far as the bearing on the conditions of accumulation of the vegetable matter is concerned, not much significance can be attached to the variation in the amount of ash in a coal bed of a small percentage above or below the original amount that may have come from the plants that formed the coal.

The analyses given in Table I. show that the mineral charcoal contains a smaller percentage of volatile matter and a larger percentage of fixed carbon than the average coal of the same bed. The proximate analyses (Table II.) of the bright and dull laminae of the bituminous coal bed, cited by Pringle[1] indicates that the dull laminae are similar in composition to mineral charcoal, as regards the smaller percentage of volatile matter, and the larger percentage of fixed carbon compared with the bright or the average coal.

TABLE II.

	Water	Volatile Matter	Fixed Carbon	Ash
Dull laminae	1.68	14.71	77.17	6.44
Bright laminae	1.75	31.63	63.96	2.66

Lesquereaux[2] described the changes that occur in the vegetable matter at the surface of swamps during dry periods as follows:

"Wherever the growth of peat in submerged bogs is checked by dryness or other causes, the upper surface of the peat becomes crusted, hardened and transformed into a thin coating quite impervious to the entrance of any kind of foreign matter, and it is upon this hard upper crust that the boggy humus forms, or whenever the land becomes resubmerged, a new peat vegetation begins. In such cases such a crust remains as a parting between two layers of peat."

Von Gumbel in 1883 suggested: "It is very probable that in occasional drying of the swamp, followed by renewal of flooding, lies the explanation of the alternating bright and dull coal bands."

In discussing the progress of putrefaction of the vegetable matter of coal, as described by Renault, David White[3] says that if uninterrupted, the process of putrefaction goes on until all the softer tissues are disintegrated and decomposed, leaving only the most indestructible parts, immersed in a dark subgelatinous, plastic or liquid mass, the fundamental matter. This fundamental matter not only envelops the undestroyed woody matter, but it infiltrates the surviving tissues to a greater or less extent. Where the impregnation is complete, we find dense, glossy, and shining coal. In many instances the impregnation has been imperfect, and sometimes intergrades to a charcoal or "mother coal."

It is thought by the writer that the oft-repeated lowering, probably of only a very few inches, of the water level in the

1. Pringle, John. Trans. Edinburgh Geol. Soc., vol. 10, pt. 1, 1912, p. 33.
2. Lesquereaux, L. Second Geol. Survey of Penna. Ann. Rept. for 1885, p. 118.
3. White, David. Some Problems in the Formation of Coal, Econ. Geology, Vol. 3, 1908, p. 303.

shallow swamps, and the consequent exposure of successive levels of the vegetable matter to the air, is the only adequate explanation that accounts for the extensive bedding planes practically free from clay sediments, the general distribution and alternation of the bright and dull laminae and the large amount of mineral charcoal in the latter, as they occur in the coal beds of Illinois. According to this view the bright laminae resulted from the imperfect putrefaction of the vegetable matter entirely under water, while the dull laminae and mineral charcoal resulted from the partial atmospheric decay previous to the more complete subaqueous putrefaction.

If the above view is correct, the dull laminae and mineral charcoal partings of the coal beds are the records of repeated interruptions of accumulation of the less woody kinds of plant material, during which the surface of the vegetable mass in the swamp was above water and exposed to partial atmospheric decay which resulted in the destruction of the softer parts of the plant tissues, leaving them in an indurated and more or less skeletonized and fibrous condition. On resubmergence these residual portions of the vegetable materials were not so readily impregnated with the fundamental matter of the bog as were those parts of the mass that had not suffered partial atmospheric decay, and hence in the process of bituminization these bands of harder, more skeletonized and so more fibrous vegetable matter became transformed into mineral charcoal. Such periods of arrested growth and accumulation of the more herbaceous and succulent kinds of aquatic plants, due to the exposure of the surface of the vegetable matter of the bog, would be favorable for the accumulation on such a surface of a relatively larger proportion of spores than would be mingled with the vegetable mass during periods of submergence and of normal vegetable growth in the bog. The resistant nature of the spore cases would also permit their better preservation than the ordinary plant tissues during such times of exposure. These conditions would explain the greater abundance of spores in the dull than in the bright laminae of the coal beds. The variation in thickness of the dull laminae is assumed to be due to the unevenness of the surface of the exposed matter in the bog. The relatively smaller percentage of volatile matter, and larger percentage of fixed carbon in the mineral charcoal and dull laminae, would be explained in part by the fact that during the times when the surface of the vegetable mass was above water and exposed to atmospheric decay, the volatile products of decomposition escaped into the air, and probably in part because the material of the dull laminae were

not subsequently infiltrated with the liquid hydrocarbons of the bog to the same extent as that of the bright laminae.

The foregoing interpretation of the structural features of the coal beds leads to the following very definite conclusions:

1. That the beginning of vegetable accumulation of the coal beds was in a very shallow swamp.

2. That the swamp deepened so slowly, either by subsidence of the area, or from the gradual building up of the border or outlet by sedimentation, or both, that the plants were able to adjust themselves to the changes, and the accumulation of vegetable matter in a general way kept pace with the increasing depth.

3. That throughout the entire period of accumulation of the coal beds the water of the swamp was so shallow that, during the oft-recurring cycles of drought, successive levels of the vegetable mass were temporarily exposed and so modified by partial atmospheric decay as to result in the formation of the dull mineral charcoal laminae.

4. That the time involved in the accumulation of the vegetable material of a coal bed was the time necessary for the growth of the plants, plus the time recorded in the partial interruptions of normal accumulation, indicated by the dull laminae and charcoal partings of the coal, which would very considerably increase the usual estimate of time required.

CONSTITUTION AND BY-LAWS

Illinois Academy of Science

CONSTITUTION

Article I. Name

This Society shall be known as The Illinois Academy of Science.

Article II. Objects

The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the scientific interests of the State.

Article III. Members

The membership of the Academy shall consist of *Active Members, Non-resident Members, Corresponding Members, Life Members and Honorary Members.*

Active Members shall be persons who are interested in scientific work and are residents of the State of Illinois. Each active member shall pay an initiation fee of one dollar and an annual assessment of one dollar.

Non-resident Members shall be persons who have been members of the Academy but have removed from the State. Their duties and privileges shall be the same as those of active members except that they may not hold office.

Corresponding Members shall be such persons actively engaged in scientific research as shall be chosen by the Academy, their duties and privileges to be the same as those of active members, except that they may not hold office and shall be free from all dues.

Life Members shall be active or non-resident members who have paid fees to the amount of twenty dollars. They shall be free from further annual dues.

Honorary Members shall be persons who have rendered distinguished service to science and who are not residents of the State of Illinois. The number shall not exceed twenty at one time. They shall be free from all dues.

For election to any class of membership the candidate's name must be proposed by two members, be approved by a majority of the committee on membership, and receive the assent of three-fourths of the members voting.

All workers in science present at the organization meeting who sign the constitution, upon payment of their initiation fee and their annual dues for 1908 become charter members.

Article IV. Officers

The officers of the Academy shall consist of a President, a Vice-President, a Chairman of each section that may be organized, a Secretary, and a Treasurer. These officers shall be chosen by ballot on recommendation of a nominating committee, at an annual meeting, and shall hold office for one year or until their successors qualify.

They shall perform the duties usually pertaining to their respective offices.

It shall be one of the duties of the President to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

The Secretary shall have charge of all the books, collections, and material property belonging to the Academy.

Article V. Council

The Council shall consist of the President, Vice-President, Chairman of each section, Secretary, Treasurer, and the president of the preceding year. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

Article VI. Standing Committees

The Standing Committees of the Academy shall be a Committee on Publication and a Committee on Membership.

The Committee on Publication shall consist of the President, the Secretary, and a third member chosen annually by the Academy.

The Committee on Membership shall consist of five members chosen annually by the Academy.

Article VII. Meetings

The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings may be called by the Council and shall be called upon written request of twenty members.

Article VIII. Publication

The regular publications of the Academy shall include the transactions of the Academy and such papers as are deemed suitable by the Committee on Publication.

All members shall receive gratis the current issues of the Academy.

Article IX. Affiliation

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council and be ordered by a three-fourths vote of the members present at any regular meeting.

Article X. Amendments

This constitution may be amended by a three-fourths vote of the members present at an annual meeting, provided that notice of the desired change has been sent by the Secretary to all members at least twenty days before such meeting.

BY-LAWS

I. The following shall be the regular order of business:

1. Call to order.
2. Reports of officers.
3. Reports of standing committees.
4. Election of members.
5. Reports of special committees.
6. Appointment of special committees.
7. Unfinished business.
8. New business.
9. Election of officers.
10. Program.

Adjournment.

II. No meeting of the Academy shall be held without thirty days' previous notice being sent by the Secretary to all members.

III. Fifteen members shall constitute a quorum of the Academy. A majority of the Council shall constitute a quorum of the Council.

IV. No bill against the Academy shall be paid without an order signed by the President and Secretary.

V. Members who shall allow their dues to remain unpaid for three years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI. The Secretary shall have charge of the distribution, sale, and exchange of the published transactions of the Academy, under such restrictions as may be imposed by the Council.

VII. The presiding officer shall at each annual meeting appoint a committee of three who shall examine and report in writing upon the account of the Treasurer.

VIII. No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary.

IX. These by-laws may be suspended by a three-fourths vote of the members present at any regular meeting.

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(Revised May, 1915.)

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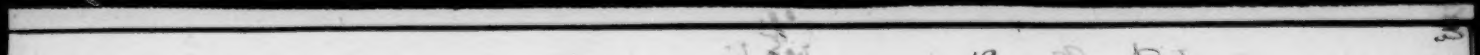
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